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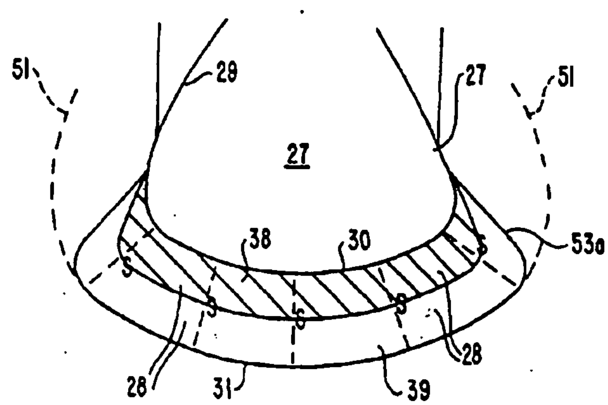
(54) **Shoe with naturally contoured sole**

(57) A shoe sole (28) for a shoe including a bottom sole (128) and a midsole (127). The shoe sole (28) is divided into medial and lateral sides and a middle portion located between the sides. The inner surface (30) of the shoe sole (28) includes a portion that is concavely rounded relative to an intended wearer's foot location inside the shoe, when the shoe sole (28) is in an upright, unloaded condition. The outer surface (31) of the shoe sole (28) has an uppermost part formed by midsole (127) which extends to at least the height of the lowest point of the inner surface (30), as viewed in a frontal plane cross-section when the shoe sole (28) is in an upright, unloaded condition. The outer surface (31) of the sole middle portion includes at least one portion that is concavely rounded relative to an intended wearer's foot location inside the shoe and which extends through the lowest point of the shoe sole (28), as viewed in a frontal plane cross-section when the shoe sole (28) is in an upright, unloaded condition.

FIG. 15



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Description

Background of the Invention

[0001] This invention relates to a shoe, such as a street shoe, athletic shoe, and especially a running shoe with a contoured sole. More particularly; this invention relates to a novel contoured sole design for a running shoe which improves the inherent stability and efficient motion of the shod foot in extreme exercise. Still more particularly, this invention relates to a running shoe wherein the shoe sole conforms to the natural shape of the foot, particularly the sides, and has a constant thickness in frontal plane cross sections, permitting the foot to react naturally with the ground as it would if the foot were bare, while continuing to protect and cushion the foot.

[0002] By way of introduction, barefoot populations universally have a very low incidence of running "overuse" injuries, despite very high activity levels. In contrast, such injuries are very common in shoe shod populations, even for activity levels well below "overuse". Thus, it is a continuing problem with a shod population to reduce or eliminate such injuries and to improve the cushioning and protection for the foot. It is primarily to an understanding of the reasons for such problems and to proposing a novel solution according to the invention to which this improved shoe is directed.

[0003] A wide variety of designs are available for running shoes which are intended to provide stability, but which lead to a constraint in the natural efficient motion of the foot and ankle. However, such designs which can accommodate free, flexible motion in contrast create a lack of control or stability. A popular existing shoe design incorporates an inverted, outwardly-flared shoe sole wherein the ground engaging surface is wider than the heel engaging portion. However, such shoes are unstable in extreme situations because the shoe sole, when inverted or on edge, immediately becomes supported only by the sharp bottom sole edge where the entire weight of the body, multiplied by a factor of approximately three at running peak, is concentrated. Since an unnatural lever arm and force moment are created under such conditions, the foot and ankle are destabilized and, in the extreme, beyond a certain point of rotation about the pivot point of the shoe sole edge, forcibly cause ankle strain. In contrast, the unshod foot is always in stable equilibrium without a comparable lever arm or force moment and, at its maximum range of inversion motion, about 20°, the base of support on the barefoot heel actually broadens substantially as the calcaneal tuberosity contacts the ground. This is in contrast to the conventionally available shoe sole bottom which maintains a sharp, unstable edge.

[0004] Existing running shoes interfere with natural foot and ankle biomechanics, disrupting natural stability and efficient natural motion. They do so by altering the natural position of the foot relative to the ground, during the load-bearing phase of running or walking. The foot in its natural, bare state is in direct contact with the ground, so its relative distance from the ground is obviously constant at zero. Even when the foot tilts naturally from side to side, either moderately when running or extremely when stumbling or tripping, the distance always remains constant at zero.

[0005] In contrast, existing shoes maintain a constant distance from the ground - the thickness of the shoe sole - only when they are perfectly flat on the ground. As soon as the shoe is tilted, the distance between foot and ground begins to change unnaturally, as the shoe sole pivots around the outside corner edge. With conventional athletic shoes, the distance most typically increases at first due to the flared sides and then decreases; many street shoes with relatively wide heel width follow that pattern, though some with narrower heels only decrease. All existing shoes continue to decrease the distance all the way down to zero, by tilting through 90 degrees, resulting in ankle sprains and breaks.

[0006] A corrected shoe sole design, however, avoids such unnatural interference by neutrally maintaining a constant distance between foot and ground, even when the shoe is tilted sideways, as if in effect the shoe sole were not there except to cushion and protect. 'Unlike existing shoes, the corrected shoe would move with the foot's natural sideways pronation and supination motion on the ground. To the problem of using a shoe sole to maintain a naturally constant distance during that sideways motion, there are two possible geometric solutions, depending upon whether just the lower horizontal plane of the shoe sole surface varies to achieve natural contour or both upper and lower surface planes vary.

[0007] In the two plane solution, the naturally contoured design, which will be described in Figures 1-28, both upper and lower surfaces or planes of the shoe sole vary to conform to the natural contour of the human foot. The two plane solution is the most fundamental concept and naturally most effective. It is the only pure geometric solution to the mathematical problem of maintaining constant distance between foot and ground, and the most optimal, in the same sense that round is only shape for a wheel and perfectly round is most optimal. On the other hand, it is the least similar to existing designs of the two possible solutions and requires computer aided design and injection molding manufacturing techniques.

[0008] In the more conventional one plane solution, the quadrant contour side design, which will be described in Figures 29-37, the side contours are formed by variations in the bottom surface alone. The upper surface or plane of the shoe sole remains unvaryingly flat in frontal plane cross sections, like most existing shoes, while the plane of the bottom shoe sole varies on the sides to provide a contour that preserves natural foot and ankle biomechanics. Though less optimal than the two plane solution, the one plane quadrant contour side design is still the only optimal single plane solution to the problem of avoiding disruption of natural human bi-

omechanics. The one plane solution is the closest to existing shoe sole design, and therefore the easiest and cheapest to manufacture with existing equipment. Since it is more conventional in appearance than the two plane solution, but less biomechanically effective, the one plane quadrant contour side design is preferable for dress or street shoes and for light exercise, like casual walking.

[0009] It is thus an overall objective of this invention to provide a novel shoe design which approximates the barefoot. It has been discovered, by investigating the most extreme range of ankle motion to near the point of ankle sprain, that the abnormal motion of an inversion ankle sprain, which is a tilting to the outside or an outward rotation of the foot, is accurately simulated while stationary. With this observation, it can be seen that the extreme range stability of the conventionally shod foot is distinctly inferior to the barefoot and that the shoe itself creates a gross instability which would otherwise not exist.

[0010] Even more important, a normal barefoot running motion, which approximately includes a 7° inversion and a 7° eversion motion, does not occur with shod feet, where a 30° inversion and eversion is common. Such a normal barefoot motion is geometrically unattainable because the average running shoe heel is approximately 60% larger than the width of the human heel. As a result, the shoe heel and the human heel cannot pivot together in a natural manner; rather, the human heel has to pivot within the shoe but is resisted from doing so by the shoe heel counter, motion control devices, and the lacing and binding of the shoe upper, as well as various types of anatomical supports interior to the shoe.

[0011] Thus, it is an overall objective to provide an improved shoe design which is not based on the inherent contradiction present in current shoe designs which make the goals of stability and efficient natural motion incompatible and even mutually exclusive. It is another overall object of the invention to provide a new contour design which simulates the natural barefoot motion in running and thus avoids the inherent contradictions in current designs.

[0012] It is another objective of this invention to provide a running shoe which overcomes the problem of the prior art.

[0013] It is another objective of this invention to provide a shoe wherein the outer extent of the flat portion of the sole of the shoe includes all of the support structures of the foot but which extends no further than the outer edge of the flat portion of the foot sole so that the transverse or horizontal plane outline of the top of the flat portion of the shoe sole coincides as nearly as possible with the load-bearing portion of the foot sole.

[0014] It is another objective of the invention to provide a shoe having a sole which includes a side contoured like the natural form of the side or edge of the human foot and conforming to it.

[0015] It is another objective of this invention to provide a novel shoe structure in which the contoured sole includes a shoe sole thickness that is precisely constant in frontal plane cross sections, and therefore biomechanically neutral, even if the shoe sole is tilted to either side, or forward or backward.

[0016] It is another objective of this invention to provide a shoe having a sole fully contoured like and conforming to the natural form of the non-load-bearing human foot and deforming under load by flattening just as the foot does.

[0017] It is still another objective of this invention to provide a new stable shoe design wherein the heel lift or wedge increases in the sagittal plane the thickness of the shoe sole or toe taper decrease therewith so that the sides of the shoe sole which naturally conform to the sides of the foot also increase or decrease by exactly the same amount, so that the thickness of the shoe sole in a frontal planar cross section is always constant.

[0018] It is another objective of this invention to provide a shoe having a shoe having a naturally contoured design as described wherein the sides of the shoe are abbreviated to essential structural support and propulsion elements to provide flexibility and in which the density of the shoe sole may be increased to compensate for increased loading.

[0019] It is another objective of this invention to provide a shoe sole design which includes a plurality of freely articulating essential structural support elements in the sole of the shoe which are consistent with the sole of the foot and are free to move independently of each other to follow the motion of the freely articulating bone structures of the foot.

[0020] It is still another object of this invention to provide a shoe of the type described wherein the material of the sole is removed except beneath essential structural support elements of the foot.

[0021] It is another object of this invention to provide a shoe of the type described with treads having an outer or a base surface which follows the theoretically ideal stability plane.

[0022] It is yet another overall object of this invention to provide a shoe construction having a design defined by the natural shape of an unloaded foot and which deforms upon loading to approximate at least the theoretically ideal stability plane.

[0023] It is still another object of this invention to provide a shoe construction wherein a plot of the range of inversion and eversion motion defines a curve with substantially no vertical component variation over a range of at least 40 degrees.

[0024] It is still another object of this invention to provide a shoe having a sole edge surface which terminates in a laterally extending portion made from a flexible material and structured to terminate upon loading in a position which approximates or is in parallel with the theoretically ideal stability plane.

[0025] It is yet another object of this invention to pro-

vide a shoe with a plurality of frontal plane slits located at predetermined locations in said shoe sole.

[0026] It is still another objective of this invention to provide a correct method of measuring the thickness of shoe sole contours.

[0027] It is another objective of the invention to provide a shoe having a sole which includes a rounded sole edge contoured like the natural form of the side or edge of the human foot but in a geometrically precise manner so that the shoe sole thickness is precisely constant, even if the shoe sole is tilted to either side, or forward or backward.

[0028] It is another objective of this invention to provide a novel shoe structure in which the contoured sole includes at its outer edge portions a contoured surface described by a radius equal to the thickness of the shoe sole with a center of rotation at the outer edge of the top of the shoe sole.

[0029] It is another objective of this invention to provide a sole structure of the type described which includes at least portions of outer edge quadrants wherein the outer edge of each quadrant coincide with the horizontal plane of the top of the sole while the other edge is perpendicular to it.

[0030] It is still another object of this invention to provide a shoe sole of the type described wherein the bottom or outer sole of the shoe includes most or all of the special contours of the new design, while other portions of the shoe such as the midsole and heel lift are produced conventionally.

[0031] It is still another object of this invention to provide a shoe of the type described which further includes enhancements which are included in the structure which defines the theoretically ideal stability plane.

[0032] It is still another object of this invention to provide a shoe of the type described wherein the enhancements which are included in the structure which defines the theoretically ideal stability plane are applied to the single plane or the dual-plane embodiments of the invention as here described.

[0033] These and other objectives of the invention will become apparent from a detailed description of the invention which follows taken in conjunction with the accompanying drawings.

Brief Description of the Drawings

[0034] In the drawings:

Fig. 1 is a perspective view of a typical running shoe known to the prior art to which the invention is applicable;

Fig. 2 shows, in Figs. 2A and 2B, the obstructed natural motion of the shoe heel in frontal planar cross section rotating inwardly or outwardly with the shoe sole having a flared bottom in a conventional prior art design such as in Fig. 1; and in Figs. 2C and 2D, the efficient motion of a narrow rectangular shoe sole design;

Fig. 3 is a frontal plane cross section showing a shoe sole of uniform thickness that conforms to the natural shape of the human foot, the novel shoe design according to the invention;

Fig. 4 shows, in Figs. 4A-4D, a load-bearing flat component of a shoe sole and naturally contoured stability side component, as well as a preferred horizontal periphery of the flat load-bearing portion of the shoe sole when using the sole of the invention;

Fig. 5 is diagrammatic sketch in Figs. 5A and 5B, showing the novel contoured side sole design according to the invention with variable heel lift;

Fig. 6 is a side view of the novel stable contoured shoe according to the invention showing the contoured side design;

Fig. 7D is a top view of the shoe sole shown in Fig. 6, wherein Fig. 7A is a cross-sectional view of the forefoot portion taken along lines 7A of Figs. 6 or 7; Fig. 7B is a view taken along lines 7B of Figs. 6 and 7; and Fig. 7C is a cross-sectional view taken along the heel along lines 7C in Figs. 6 and 7;

Fig. 8 is a drawn comparison between a conventional flared sole shoe of the prior art and the contoured shoe sole design according to the invention;

Fig. 9 shows, in Figs. 9A-9C, the extremely stable conditions for the novel shoe sole according to the invention in its neutral and extreme situations;

Fig. 10 is a side cross-sectional view of the naturally contoured sole side showing in Fig. 10A how the sole maintains a constant distance from the ground during rotation of the shoe edge; and showing in Fig. 10B how a conventional shoe sole side cannot maintain a constant distance from the ground.

Fig. 11 shows, in Figs. 11A-11E, a plurality of side sagittal plane cross-sectional views showing examples of conventional sole thickness variations to which the invention can be applied;

Fig. 12 shows, in Figs. 12A-12D, frontal plane cross-sectional views of the shoe sole according to the invention showing a theoretically ideal stability plane and truncations of the sole side contour to reduce shoe bulk;

Fig. 13 shows, in Figs. 13A-13C, the contoured sole design according to the invention when applied to various tread and cleat patterns;

Fig. 14 illustrates, in a rear view, an application of the sole according to the invention to a shoe to provide an aesthetically pleasing and functionally effective design;

Fig. 15 shows a fully contoured shoe sole design that follows the natural contour of the bottom of the foot as well as the sides.

Fig. 16 is a diagrammatic frontal plane cross-sectional view of static forces acting on the ankle joint and its position relative to the shoe sole according to the invention during normal and extreme inversion and eversion motion.

Fig. 17 is a diagrammatic frontal plane view of a plurality of moment curves of the center of gravity for various degrees of inversion for the shoe sole according to the invention, and contrasted to the motions shown in Fig. 2;

Fig. 18 shows, in Figs. 18A and 18B, a rear diagrammatic view of a human heel, as relating to a conventional shoe sole (Fig. 18A) and to the sole of the invention (Fig. 18B);

Fig. 19 shows the naturally contoured sides design extended to the other natural contours underneath the load-bearing foot such as the main longitudinal arch;

Fig. 20 illustrates the fully contoured shoe sole design extended to the bottom of the entire non-load-bearing foot;

Fig. 21 shows the fully contoured shoe sole design abbreviated along the sides to only essential structural support and propulsion elements;

Fig. 22 illustrates the application of the invention to provide a street shoe with a correctly contoured sole according to the invention and side edges perpendicular to the ground, as is typical of a street shoe;

Fig. 23 shows a method of establishing the theoretically ideal stability plane using a perpendicular to a tangent method;

Fig. 24 shows a circle radius method of establishing the theoretically ideal stability plane.

Fig. 25 illustrates an alternate embodiment of the invention wherein the sole structure deforms in use to follow a theoretically ideal stability plane according to the invention during deformation;

Fig. 26 shows an embodiment wherein the contour of the sole according to the invention is approximated by a plurality of line segments;

Fig. 27 illustrates an embodiment wherein the stability sides are determined geometrically as a section of a ring; and

Fig. 28 shows a shoe sole design that allows for unobstructed natural eversion/inversion motion by providing torsional flexibility in the instep area of the shoe sole.

Fig. 29 is a diagrammatic chart showing, in Figs. 29A-29C, the outer contoured sides related to the sole of the novel shoe design according to the invention;

Fig. 30 is diagrammatic sketch in Figs. 30A and 30B, showing the novel contoured side sole design according to the invention with variable heel lift;

Fig. 31 is a side cross-sectional view of the quadrant sole side showing how the sole maintains a constant distance from the ground during rotation of the shoe edge;

Fig. 32 shows, in Figs. 32A-32C, frontal plane cross-sectional views of the shoe sole according to the invention showing a theoretically ideal stability plane and truncations of the sole edge quadrant to reduce shoe bulk;

Fig. 33 illustrates, in Figs. 33A-33C, heel cross sectional views of a conventional street shoe (Fig. 33A), and the application of the invention shown in Fig. 33B to provide a street shoe (Fig. 33C) with a correctly contoured sole according to the invention;

Fig. 34 shows, in a diagrammatic rear view, a relationship between the calcaneal tuberosity of the foot and the use of a wedge with the shoe of the invention;

Fig. 35 illustrates an alternate embodiment of the invention wherein the sole structure deforms in use to follow a theoretically ideal stability plane according to the invention during deformation;

Fig. 36 shows an embodiment wherein the contour of the sole according to the invention is approximated by a plurality of chord segments; and

Fig. 37 shows in a diagrammatic view the theoretically ideal stability plane.

Fig. 38 shows several embodiments wherein the bottom sole includes most or all of the special contours of the new designs and retains a flat upper surface.

Fig. 39, in Figs. 39A - 39C, show frontal plane cross sections of an enhancement to the previously-described embodiment.

Fig. 40 shows, in Figs. 40A - 40C, the enhancement of Fig. 39 applied to the naturally contoured sides embodiment of the invention.

Detailed Description of the Preferred Embodiment

[0035] A perspective view of an athletic shoe, such as a typical running shoe, according to the prior art, is shown in Fig. 1 wherein a running shoe 20 includes an upper portion 21 and a sole 22. Typically, such a sole includes a truncated outwardly flared construction of the type best seen in Fig. 2 wherein the lower portion 22a of the sole heel is significantly wider than the upper portion 22b where the sole 22 joins the upper 21. A number of alternative sole designs are known to the art, including the design shown in U.S. Patent No. 4,449,306 to Cavanagh wherein an outer portion of the sole of the running shoe includes a rounded portion having a radius of curvature of about 20mm. The rounded portion lies along approximately the rear-half of the length of the outer side of the midsole and heel edge areas wherein the remaining border area is provided with a conventional flaring with the exception of a transition zone. The U.S. Patent to Misevich, No. 4,557,059 also shows an athletic shoe having a contoured sole bottom in the region of the first foot strike, in a shoe which otherwise uses an inverted flared sole.

[0036] In such prior art designs, and especially in athletic and in running shoes, the typical design attempts to achieve stability by flaring the heel as shown in Figs. 2A and 2B to a width of, for example, 3 to 3-1/2 inches on the bottom outer sole 22a of the average male shoe size (10D). On the other hand, the width of the corre-

sponding human heel foot print, housed in the upper 21, is only about 2.25 in. for the average foot. Therefore, a mismatch occurs in that the heel is locked by the design into a firm shoe heel counter which supports the human heel by holding it tightly and which may also be re-enforced by motion control devices to stabilize the heel. Thus, for natural motion as is shown in Figs. 2A and 2B, the human heel would normally move in a normal range of motion of approximately 15°, but as shown in Figs. 2A and 2B the human heel cannot pivot except within the shoe and is resisted by the shoe. Thus, Fig. 2A illustrates the impossibility of pivoting about the center edge of the human heel as would be conventional for barefoot support about a point 23 defined by a line 23a perpendicular to the heel and intersecting the bottom edge of upper 21 at a point 24. The lever arm force moment of the flared sole is at a maximum at 0° and only slightly less at a normal 7° inversion or eversion and thus strongly resists such a natural motion as is illustrated in Figs. 2A and 2B. In Fig. 2A, the outer edge of the heel must compress to accommodate such motion. Fig. 2B illustrates that normal natural motion of the shoe is inefficient in that the center of gravity of the shoe, and the shod foot, is forced upwardly, as discussed later in connection with Fig. 17.

[0037] A narrow rectangular shoe sole design of heel width approximating human heel width is also known and is shown in Figs. 2C and 2D. It appears to be more efficient than the conventional flared sole shown in Figs. 2A and 2B. Since the shoe sole width is the same as human sole width, the shoe can pivot naturally with the normal 7° inversion/ eversion motion of the running barefoot. In such a design, the lever arm length and the vertical motion of the center of gravity are approximately half that of the flared sole at a normal 7° inversion/eversion running motion. However, the narrow, human heel width rectangular shoe design is extremely unstable and therefore prone to ankle sprain, so that it has not been well received. Thus, neither of these wide or narrow designs is satisfactory.

[0038] Fig. 3 shows in a frontal plane cross section at the heel (center of ankle joint) the general concept of the applicant's design: a shoe sole 28 that conforms to the natural shape of the human foot 27 and that has a constant thickness (s) in frontal plane cross sections. The surface 29 of the bottom and sides of the foot 27 should correspond exactly to the upper surface 30 of the shoe sole 28. The shoe sole thickness is defined as the shortest distance (s) between any point on the upper surface 30 of the shoe sole 28 and the lower surface 31 (Figs. 23 and 24 will discuss measurement methods more fully). In effect, the applicant's general concept is a shoe sole 28 that wraps around and conforms to the natural contours of the foot 27 as if the shoe sole 28 were made of a theoretical single flat sheet of shoe sole material of uniform thickness, wrapped around the foot with no distortion or deformation of that sheet as it is bent to the foot's contours. To overcome real world deformation problems associated with such bending or wrapping around contours, actual construction of the shoe sole contours of uniform thickness will preferably involve the use of multiple sheet lamination or injection molding techniques.

[0039] Figs. 4A, 4B, and 4C illustrate in frontal plane cross section a significant element of the applicant's shoe design in its use of naturally contoured stabilizing sides 28a at the outer edge of a shoe sole 28b illustrated generally at the reference numeral 28. It is thus a main feature of the applicant's invention to eliminate the unnatural sharp bottom edge, especially of flared shoes, in favor of a naturally contoured shoe sole outside 31 as shown in Fig. 3. The side or inner edge 30a of the shoe sole stability side 28a is contoured like the natural form on the side or edge of the human foot, as is the outside or outer edge 31a of the shoe sole stability side 28a to follow a theoretically ideal stability plane. According to the invention, the thickness (s) of the shoe sole 28 is maintained exactly constant, even if the shoe sole is tilted to either side, or forward or backward. Thus, the naturally contoured stabilizing sides 28a, according to the applicant's invention, are defined as the same as the thickness 33 of the shoe sole 28 so that, in cross section, the shoe sole comprises a stable shoe sole 28 having at its outer edge naturally contoured stabilizing sides 28a with a surface 31a representing a portion of a theoretically ideal stability plane and described by naturally contoured sides equal to the thickness (s) of the sole 28. The top of the shoe sole 30b coincides with the shoe wearer's load-bearing footprint, since in the case shown the shape of the foot is assumed to be load-bearing and therefore flat along the bottom. A top edge 32 of the naturally contoured stability side 28a can be located at any point along the contoured side 29 of the foot, while the inner edge 33 of the naturally contoured side 28a coincides with the perpendicular sides 34 of the load-bearing shoe sole 28b. In practice, the shoe sole 28 is preferably integrally formed from the portions 28b and 28a. Thus, the theoretically ideal stability plane includes the contours 31a merging into the lower surface 31b of the sole 28.

[0040] Preferably, the peripheral extent 36 of the load-bearing portion of the sole 28b of the shoe includes all of the support structures of the foot but extends no further than the outer edge of the foot sole 37 as defined by a load-bearing footprint, as shown in Fig. 4D, which is a top view of the upper shoe sole surface 30b. Fig. 4D thus illustrates a foot outline at numeral 37 and a recommended sole outline 36 relative thereto. Thus, a horizontal plane outline of the top of the load-bearing portion of the shoe sole, therefore exclusive of contoured stability sides, should, preferably, coincide as nearly as practicable with the load-bearing portion of the foot sole with which it comes into contact. Such a horizontal outline, as best seen in Figs. 4D and 7D, should remain uniform throughout the entire thickness of the shoe sole eliminating negative or positive sole flare so

that the sides are exactly perpendicular to the horizontal plane as shown in Fig. 4B. Preferably, the density of the shoe sole material is uniform.

[0041] Another significant feature of the applicant's invention is illustrated diagrammatically in Fig. 5. Preferably, as the heel lift or wedge 38 of thickness (s1) increases the total thickness (s + s1) of the combined midsole and outersole 39 of thickness (s) in an aft direction of the shoe, the naturally contoured sides 28a increase in thickness exactly the same amount according to the principles discussed in connection with Fig. 4. Thus, according to the applicant's design, the thickness of the inner edge 33 of the naturally contoured side is always equal to the constant thickness (s) of the load-bearing shoe sole 28b in the frontal cross-sectional plane.

[0042] As shown in Fig. 5B, for a shoe that follows a more conventional horizontal plane outline, the sole can be improved significantly according to the applicant's invention by the addition of a naturally contoured side 28a which correspondingly varies with the thickness of the shoe sole and changes in the frontal plane according to the shoe heel lift 38. Thus, as illustrated in Fig. 5B, the thickness of the naturally contoured side 28a in the heel section is equal to the thickness (s + s1) of the shoe sole 28 which is thicker than the shoe sole 39 thickness (s) shown in Fig. 5A by an amount equivalent to the heel lift 38 thickness (s1). In the generalized case, the thickness (s) of the contoured side is thus always equal to the thickness (s) of the shoe sole.

[0043] Fig. 6 illustrates a side cross-sectional view of a shoe to which the invention has been applied and is also shown in a top plane view in Fig. 7. Thus, Figs. 7A, 7B and 7C represent frontal plane cross-sections taken along the forefoot, at the base of the fifth metatarsal, and at the heel, thus illustrating that the shoe sole thickness is constant at each frontal plane cross-section, even though that thickness varies from front to back, due to the heel lift 38 as shown in Fig. 6, and that the thickness of the naturally contoured sides is equal to the shoe sole thickness in each Fig. 7A-7C cross section. Moreover, in Fig. 7D, a horizontal plane overview of the left foot, it can be seen that the contour of the sole follows the preferred principle in matching, as nearly as practical, the load-bearing sole print shown in Fig. 4D.Fig. 8 thus contrasts in frontal plane cross section the conventional flared sole 22 shown in phantom outline and illustrated in Fig. 2 with the contoured shoe sole 28 according to the invention as shown in Figs. 3-7.

[0044] Fig. 9 is suitable for analyzing the shoe sole design according to the applicant's invention by contrasting the neutral situation shown in Fig. 9A with the extreme situations shown in Figs. 9B and 9C. Unlike the sharp sole edge of a conventional shoe as shown in Fig. 2, the effect of the applicant's invention having a naturally contoured side 28a is totally neutral allowing the shod foot to react naturally with the ground 43, in either an inversion or eversion mode. This occurs in part because of the unvarying thickness along the shoe sole edge which keeps the foot sole equidistant from the ground in a preferred case. Moreover, because the shape of the edge 31a of the shoe contoured side 28a is exactly like that of the edge of the foot, the shoe is enabled to react naturally with the ground in a manner as closely as possible simulating the foot. Thus, in the neutral position shown in Fig. 9, any point 40 on the surface of the shoe sole 30b closest to ground lies at a distance (s) from the ground surface 43. That distance (s) remains constant even for extreme situations as seen in Figs. 9B and 9C.

[0045] A main point of the applicant's invention, as is illustrated in Figs. 9B and 9C, is that the design shown is stable in an <u>in extremis</u> situation. The theoretically ideal plane of stability is where the stability plane is defined as sole thickness which is constant under all load-bearing points of the foot sole for any amount from 0° to 90° rotation of the sole to either side or front and back. In other words, as shown in Fig. 9, if the shoe is tilted from 0° to 90° to either side or from 0° to 90° forward or backward representing a 0° to 90° foot dorsiflexion or 0° to 90° plantarflexion, the foot will remain stable because the sole thickness (s) between the foot and the ground always remain constant because of the exactly contoured quadrant sides. By remaining a constant distance from the ground, the stable shoe allows the foot to react to the ground as if the foot were bare while allowing the foot to be protected and cushioned by the shoe. In its preferred embodiment, the new naturally contoured sides will effectively position and hold the foot onto the load-bearing foot print section of the shoe sole, reducing or eliminating the need for heel counters and other relatively rigid motion control devices.

[0046] Fig. 10A illustrates how the inner edge 30a of the naturally contoured sole side 28a is maintained at a constant distance (s) from the ground through various degrees of rotation of the edge 31a of the shoe sole such as is shown in Fig. 9. Figure 10B shows how a conventional shoe sole pivots around its lower edge 42, which is its center of rotation, instead of around the upper edge 40, which, as a result, is not maintained at constant distance (s) from the ground, as with the invention, but is lowered to .7(s) at 45° rotation and to zero at 90° rotation.

[0047] Fig. 11 shows typical conventional sagittal plane shoe sole thickness variations, such as heel lifts or wedges 38, or toe taper 38a, or full sole taper 38b, in Figs. 11A-11E and how the naturally contoured sides 28a equal and therefore vary with those varying thicknesses as discussed in connection with Fig. 5.

[0048] Fig. 12 illustrates an embodiment of the invention which utilizes varying portions of the theoretically ideal stability plane 51 in the naturally contoured sides 28a in order to reduce the weight and bulk of the sole, while accepting a sacrifice in some stability of the shoe. Thus, Fig. 12A illustrates the preferred embodiment as described above in connection with Fig. 5 wherein the outer edge 31a of the naturally contoured sides 28a fol-

lows a theoretically ideal stability plane 51. As in Figs. 3 and 4, the contoured surfaces 31a, and the lower surface of the sole 31b lie along the theoretically ideal stability plane 51. The theoretically ideal stability plane 51 is defined as the plane of the surface of the bottom of the shoe sole 31, wherein the shoe sole conforms to the natural shape of the foot, particularly the sides, and has a constant thickness in frontal plane cross sections. As shown in Fig. 12B, an engineering trade-off results in an abbreviation within the theoretically ideal stability plane 51 by forming a naturally contoured side surface 53a approximating the natural contour of the foot (or more geometrically regular, which is less preferred) at an angle relative to the upper plane of the shoe sole 28 so that only a smaller portion of the contoured side 28a defined by the constant thickness lying along the surface 31a is coplanar with the theoretically ideal stability plane 51. Figs. 12C and 12D show similar embodiments wherein each engineering trade-off shown results in progressively smaller portions of contoured side 28a, which lies along the theoretically ideal stability plane 51. The portion of the surface 31a merges into the upper side surface 53a of the naturally contoured side.

[0049] The embodiment of Fig. 12 may be desirable for portions of the shoe sole which are less frequently used so that the additional part of the side is used less frequently. For example, a shoe may typically roll out laterally, in an inversion mode, to about 20° on the order of 100 times for each single time it rolls out to 40°. For a basketball shoe, shown in Fig. 12B, the extra stability is needed. Yet, the added shoe weight to cover that infrequently experienced range of motion is about equivalent to covering the frequently encounter range. Since, in a racing shoe this weight might not be desirable, an engineering trade-off of the type shown in Fig. 12D is possible. A typical running/jogging shoe is shown in Fig. 12C. The range of possible variations is limitless.

[0050] Fig. 13 shows the theoretically ideal stability plane 51 in defining embodiments of the shoe sole having differing tread or cleat patterns. Thus, Fig. 13 illustrates that the invention is applicable to shoe soles having conventional bottom treads. Accordingly, Fig. 13A is similar to Fig. 12B further including a tread portion 60, while Fig. 13B is also similar to Fig. 12B wherein the sole includes a cleated portion 61. The surface 63 to which the cleat bases are affixed should preferably be on the same plane and parallel the theoretically ideal stability plane 51, since in soft ground that surface rather than the cleats become load-bearing. The embodiment in Fig. 13C is similar to Fig. 12C showing still an alternative tread construction 62. In each case, the load-bearing outer surface of the tread or cleat pattern 60-62 lies along the theoretically ideal stability plane 51.

[0051] Fig. 14 shows, in a rear cross sectional view, the application of the invention to a shoe to produce an aesthetically pleasing and functionally effective design. Thus, a practical design of a shoe incorporating the invention is feasible, even when applied to shoes incorporating heel lifts 38 and a combined midsole and outersole 39. Thus, use of a sole surface and sole outer contour which track the theoretically ideal stability plane does not detract from the commercial appeal of shoes incorporating the invention.

[0052] Fig. 15 shows a fully contoured shoe sole design that follows the natural contour of all of the foot, the bottom as well as the sides. The fully contoured shoe sole assumes that the resulting slightly rounded bottom when unloaded will deform under load and flatten just as the human foot bottom is slightly rounded unloaded but flattens under load; therefore, shoe sole material must be of such composition as to allow the natural deformation following that of the foot. The design applies particularly to the heel, but to the rest of the shoe sole as well. By providing the closest match to the natural shape of the foot, the fully contoured design allows the foot to function as naturally as possible. Under load, Fig. 15 would deform by flattening to look essentially like Fig. 14. Seen in this light, the naturally contoured side design in Fig. 14 is a more conventional, conservative design that is a special case of the more general fully contoured design in Fig. 15, which is the closest to the natural form of the foot, but the least conventional. The amount of deformation flattening used in the Fig. 14 design, which obviously varies under different loads, is not an essential element of the applicant's invention.

[0053] Figs. 14 and 15 both show in frontal plane cross section the essential concept underlying this invention, the theoretically ideal stability plane, which is also theoretically ideal for efficient natural motion of all kinds, including running, jogging or walking. Fig. 15 shows the most general case of the invention, the fully contoured design, which conforms to the natural shape of the unloaded foot. For any given individual, the theoretically ideal stability plane 51 is determined, first, by the desired shoe sole thickness (s) in a frontal plane cross section, and, second, by the natural shape of the individual's foot surface 29.

[0054] For the special case shown in Fig. 14, the theoretically ideal stability plane for any particular individual (or size average of individuals) is determined, first, by the given frontal plane cross section shoe sole thickness (s); second, by the natural shape of the individual's foot; and, third, by the frontal plane cross section width of the individual's load-bearing footprint 30b, which is defined as the upper surface of the shoe sole that is in physical contact with and supports the human foot sole, as shown in Fig. 4.

[0055] The theoretically ideal stability plane for the special case is composed conceptually of two parts. Shown in Figs. 14 and 4 the first part is a line segment 31b of equal length and parallel to 30b at a constant distance (s) equal to shoe sole thickness. This corresponds to a conventional shoe sole directly underneath the human foot, and also corresponds to the flattened portion of the bottom of the load-bearing foot sole 28b. The second part is the naturally contoured stability side

outer edge 31a located at each side of the first part, line segment 31b. Each point on the contoured side outer edge 31a is located at a distance which is exactly shoe sole thickness (s) from the closest point on the contoured side inner edge 30a.

[0056] In summary, the theoretically ideal stability plane is the essence of this invention because it is used to determine a geometrically precise bottom contour of the shoe sole based on a top contour that conforms to the contour of the foot. This invention specifically claims the exactly determined geometric relationship just described. It can be stated unequivocally that any shoe sole contour, even of similar contour, that exceeds the theoretically ideal stability plane will restrict natural foot motion, while any less than that plane will degrade natural stability, in direct proportion to the amount of the deviation.

[0057] Fig. 16 illustrates in a curve 70 the range of side to side inversion/eversion motion of the ankle center of gravity 71 from the shoe according to the invention shown in frontal plane cross section at the ankle. Thus, in a static case where the center of gravity 71 lies at approximately the mid-point of the sole, and assuming that the shoe inverts or everts from 0° to 20° to 40°, as shown in progressions 16A, 16B and 16C, the locus of points of motion for the center of gravity thus defines the curve 70 wherein the center of gravity 71 maintains a steady level motion with no vertical component through 40° of inversion or eversion. For the embodiment shown, the shoe sole stability equilibrium point is at 28° (at point 74) and in no case is there a pivoting edge to define a rotation point as in the case of Fig. 2. The inherently superior side to side stability of the design provides pronation control (or eversion), as well as lateral (or inversion) control. In marked contrast to conventional shoe sole designs, the applicant's shoe design creates virtually no abnormal torque to resist natural inversion/eversion motion or to destabilize the ankle joint.

[0058] Fig. 17 thus compares the range of motion of the center of gravity for the invention, as shown in curve 70, in comparison to curve 80 for the conventional wide heel flare and a curve 82 for a narrow rectangle the width of a human heel. Since the shoe stability limit is 28° in the inverted mode, the shoe sole is stable at the 20° approximate barefoot inversion limit. That factor, and the broad base of support rather than the sharp bottom edge of the prior art, make the contour design stable even in the most extreme case as shown in Figs. 16A-16C and permit the inherent stability of the barefoot to dominate without interference, unlike existing designs, by providing constant, unvarying shoe sole thickness in frontal plane cross sections. The stability superiority of the contour side design is thus clear when observing how much flatter its center of gravity curve 70 is than in existing popular wide flare design 80. The curve demonstrates that the contour side design has significantly more efficient natural 7° inversion/eversion motion than the narrow rectangle design the width of a human heel, and very much more efficient than the conventional wide flare design; at the same time, the contour side design is more stable <u>in extremis</u> than either conventional design because of the absence of destabilizing torque.

[0059] Fig. 18A illustrates, in a pictorial fashion, a comparison of a cross section at the ankle joint of a conventional shoe with a cross section of a shoe according to the invention when engaging a heel. As seen in Fig. 18A, when the heel of the foot 27 of the wearer engages an upper surface of the shoe sole 22, the shape of the foot heel and the shoe sole is such that the conventional shoe sole 22 conforms to the contour of the ground 43 and not to the contour of the sides of the foot 27. As a result, the conventional shoe sole 22 cannot follow the natural 7° inversion/eversion motion of the foot, and that normal motion is resisted by the shoe upper 21, especially when strongly reinforced by firm heel counters and motion control devices. This interference with natural motion represents the fundamental misconception of the currently available designs. That misconception on which existing shoe designs are based is that, while shoe uppers are considered as a part of the foot and conform to the shape of the foot, the shoe sole is functionally conceived of as a part of the ground and is therefore shaped like the ground, rather than the foot.

[0060] In contrast, the new design, as illustrated in Fig. 18B, illustrates a correct conception of the shoe sole 28 as a part of the foot and an extension of the foot, with shoe sole sides contoured exactly like those of the foot, and with the frontal plane thickness of the shoe sole between the foot and the ground always the same and therefore completely neutral to the natural motion of the foot. With the correct basic conception, as described in connection with this invention, the shoe can move naturally with the foot, instead of restraining it, so both natural stability and natural efficient motion coexist in the same shoe, with no inherent contradiction in design goals.

[0061] Thus, the contoured shoe design of the invention brings together in one shoe design the cushioning and protection typical of modern shoes, with the freedom from injury and functional efficiency, meaning speed, and/or endurance, typical of barefoot stability and natural freedom of motion. Significant speed and endurance improvements are anticipated, based on both improved efficiency and on the ability of a user to train harder without injury.

[0062] These figures also illustrate that the shoe heel cannot pivot plus or minus 7 degrees with the prior art shoe of Fig. 18A. In contrast, the shoe heel in the embodiment of Fig. 18B pivots with the natural motion of the foot heel.

[0063] Figs. 19A-D illustrate, in frontal plane cross sections, the naturally contoured sides design extended to the other natural contours underneath the load-bearing foot, such as the main longitudinal arch, the metatarsal (or forefoot) arch, and the ridge between the heads of the metatarsals (forefoot) and the heads of the

distal phalanges (toes). As shown, the shoe sole thickness remains constant as the contour of the shoe sole follows that of the sides and bottom of the load-bearing foot. Fig. 19E shows a sagittal plane cross section of the shoe sole conforming to the contour of the bottom of the load-bearing foot, with thickness varying according to the heel lift 38. Fig. 19F shows a horizontal plane top view of the left foot that shows the areas 85 of the shoe sole that correspond to the flattened portions of the foot sole that are in contact with the ground when load-bearing. Contour lines 86 and 87 show approximately the relative height of the shoe sole contours above the flattened load-bearing areas 85 but within roughly the peripheral extent 35 of the upper surface of sole 30 shown in Fig. 4. A horizontal plane bottom view (not shown) of Fig. 19F would be the exact reciprocal or converse of Fig. 19F (i.e. peaks and valleys contours would be exactly reversed).

[0064] Figs. 20A-D show, in frontal plane cross sections, the fully contoured shoe sole design extended to the bottom of the entire non-load-bearing foot. Fig. 20E shows a sagittal plane cross section. The shoe sole contours underneath the foot are the same as Figs. 19A-E except that there are no flattened areas corresponding to the flattened areas of the load-bearing foot. The exclusively rounded contours of the shoe sole follow those of the unloaded foot. A heel lift 38, the same as that of Fig. 19, is incorporated in this embodiment, but is not shown in Fig. 20.

[0065] Fig. 21 shows the horizontal plane top view of the left foot corresponding to the fully contoured design described in Figs. 20A-E, but abbreviated along the sides to only essential structural support and propulsion elements. Shoe sole material density can be increased in the unabbreviated essential elements to cqmpensate for increased pressure loading there. The essential structural support elements are the base and lateral tuberosity of the calcaneus 95, the heads of the metatarsals 96, and the base of the fifth metatarsal 97. They must be supported both underneath and to the outside for stability. The essential propulsion element is the head of first distal phalange 98. The medial (inside) and lateral (outside) sides supporting the base of the calcaneus are shown in Fig. 21 oriented roughly along either side of the horizontal plane subtalar ankle joint axis, but can be located also more conventionally along the longitudinal axis of the shoe sole. Fig. 21 shows that the naturally contoured stability sides need not be used except in the identified essential areas. Weight savings and flexibility improvements can be made by omitting the non-essential stability sides. Contour lines 85 through 89 show approximately the relative height of the shoe sole contours within roughly the peripheral extent 35 of the undeformed upper surface of shoe sole 30 shown in Fig. 4. A horizontal plane bottom view (not shown) of Fig. 21 would be the exact reciprocal or converse of Fig. 21 (i.e. peaks and valleys contours would be exactly reversed).

[0066] Fig. 22A shows a development of street shoes with naturally contoured sole sides incorporating the features of the invention. Fig. 22A develops a theoretically ideal stability plane 51, as described above, for such a street shoe, wherein the thickness of the naturally contoured sides equals the shoe sole thickness. The resulting street shoe with a correctly contoured sole is thus shown in frontal plane heel cross section in Fig. 22A, with side edges perpendicular to the ground, as is typical. Fig. 22B shows a similar street shoe with a fully contoured design, including the bottom of the sole. Accordingly, the invention can be applied to an unconventional heel lift shoe, like a simple wedge, or to the most conventional design of a typical walking shoe with its heel separated from the forefoot by a hollow under the instep. The invention can be applied just at the shoe heel or to the entire shoe sole. With the invention, as so applied, the stability and natural motion of any existing shoe design, except high heels or spike heels, can be significantly improved by the naturally contoured shoe sole design.

[0067] Fig. 23 shows a method of measuring shoe sole thickness to be used to construct the theoretically ideal stability plane of the naturally contoured side design. The constant shoe sole thickness of this design is measured at any point on the contoured sides along a line that, first, is perpendicular to a line tangent to that point on the surface of the naturally contoured side of the foot sole and, second, that passes through the same foot sole surface point.

[0068] Fig. 24 illustrates another approach to constructing the theoretically ideal stability plane, and one that is easier to use, the circle radius method. By that method, the pivot point (circle center) of a compass is placed at the beginning of the foot sole's natural side contour (frontal plane cross section) and roughly a 90° arc (or much less, if estimated accurately) of a circle of radius equal to (s) or shoe sole thickness is drawn describing the area farthest away from the foot sole contour. That process is repeated all along the foot sole's natural side contour at very small intervals (the smaller, the more accurate). When all the circle sections are drawn, the outer edge farthest from the foot sole contour (again, frontal plane cross section) is established at a distance of "s" and that outer edge coincides with the theoretically ideal stability plane. Both this method and that described in Fig. 23 would be used for both manual and CADCAM design applications.

[0069] The shoe sole according to the invention can be made by approximating the contours, as indicated in Figs. 25A, 25B, and 26. Fig. 25A shows a frontal plane cross section of a design wherein the sole material in areas 107 is so relatively soft that it deforms easily to the contour of shoe sole 28 of the proposed invention. In the proposed approximation as seen in Fig. 258, the heel cross section includes a sole upper surface 101 and a bottom sole edge surface 102 following when deformed an inset theoretically ideal stability plane 51. The

sole edge surface 102 terminates in a laterally extending portion 103 joined to the heel of the sole 28. The laterally-extending portion 103 is made from a flexible material and structured to cause its lower surface 102 to terminate during deformation to parallel the inset theoretically ideal stability plane 51. Sole material in specific areas 107 is extremely soft to allow sufficient deformation. Thus, in a dynamic case, the outer edge contour assumes approximately the theoretically ideal stability shape described above as a result of the deformation of the portion 103. The top surface 101 similarly deforms to approximately parallel the natural contour of the foot as described by lines 30a and 30b shown in Fig. 4.

[0070] It is presently contemplated that the controlled or programmed deformation can be provided by either of two techniques. In one, the shoe sole sides, at especially the midsole, can be cut in a tapered fashion or grooved so that the bottom sole bends inwardly under pressure to the correct contour. The second uses an easily deformable material 107 in a tapered manner on the sides to deform under pressure to the correct contour. While such techniques produce stability and natural motion results which are a significant improvement over conventional designs, they are inherently inferior to contours produced by simple geometric shaping. First, the actual deformation must be produced by pressure which is unnatural and does not occur with a bare foot and second, only approximations are possible by deformation, even with sophisticated design and manufacturing techniques, given an individuals particular running gait or body weight. Thus, the deformation process is limited to a minor effort to correct the contours from surfaces approximating the ideal curve in the first instance.

[0071] The theoretically ideal stability plane can also be approximated by a plurality of line segments 110, such as tangents, chords, or other lines, as shown in Fig. 26. Both the upper surface of the shoe sole 28, which coincides with the side of the foot 30a, and the bottom surface 31a of the naturally contoured side can be approximated. While a single flat plane 110 approximation may correct many of the biomechanical problems occurring with existing designs, because it can provide a gross approximation of the both natural contour of the foot and the theoretically ideal stability plane 51, the single plane approximation is presently not preferred, since it is the least optimal. By increasing the number of flat planar surfaces formed, the curve more closely approximates the ideal exact design contours, as previously described. Single and double plane approximations are shown as line segments in the cross section illustrated in Fig. 26.

[0072] Fig. 27 shows a frontal plane cross section of an alternate embodiment for the invention showing stability sides component 28a that are determined in a mathematically precise manner to conform approximately to the sides of the foot. (The center or load-bearing shoe sole component 28b would be as described in Fig. 4.) The component sides 28a would be a quadrant of a circle of radius $(r + r^1)$, where distance (r) must equal sole thickness (s); consequently the sub-quadrant of radius (r^1) is removed from quadrant $(r + r^1)$. In geometric terms, the component side 28a is thus a quarter or other section of a ring. The center of rotation 115 of the quadrants is selected to achieve a sole upper side surface 30a that closely approximates the natural contour of the side of the human foot.

[0073] Fig. 27 provides a direct bridge to another invention by the applicant, a shoe sole design with quadrant stability sides.

[0074] Fig. 28 shows a shoe sole design that allows fbr unobstructed natural inversion/eversion motion of the calcaneus by providing maximum shoe sole flexibility particularly between the base of the calcaneus 125 (heel) and the metatarsal heads 126 (forefoot) along an axis 120. An unnatural torsion occurs about that axis if flexibility is insufficient so that a conventional shoe sole interferes with the inversion/eversion motion by restraining it. The object of the design is to allow the relatively more mobile (in eversion and inversion) calcaneus to articulate freely and independently from the relatively more fixed forefoot, instead of the fixed or fused structure or lack of stable structure between the two in conventional designs. In a sense, freely articulating joints are created in the shoe sole that parallel those of the foot. The design is to remove nearly all of the shoe sole material between the heel and the forefoot, except under one of the previously described essential structural support elements, the base of the fifth metatarsal 97. An optional support for the main longitudinal arch 121 may also be retained for runners with substantial foot pronation, although would not be necessary for many runners. The forefoot can be subdivided (not shown) into its component essential structural support and propulsion elements, the individual heads of the metatarsal and the heads of the distal phalanges, so that each major articulating joint set of the foot is paralleled by a freely articulating shoe sole support propulsion element, an anthropomorphic design; various aggregations of the subdivisions are also possible. An added benefit of the design is to provide better flexibility along axis 122 for the forefoot during the toe-off propulsive phase of the running stride, even in the absence of any other embodiments of the applicant's invention; that is, the benefit exists for conventional shoe sole designs.

[0075] Fig. 28A shows in sagittal plane cross section a specific design maximizing flexibility, with large nonessential sections removed for flexibility and connected by only a top layer (horizontal plane) of non-stretching fabric 123 like Dacron polyester or Kevlar. Fig. 28B shows another specific design with a thin top sole layer 124 instead of fabric and a different structure for the flexibility sections: a design variation that provides greater structural support, but less flexibility, though still much more than conventional designs. Not shown is a simple, minimalist approach, which is comprised of single fron-

tal plane slits in the shoe sole material (all layers or part): the first midway between the base of the calcaneus and the base of the fifth metatarsal, and the second midway between that base and the metatarsal heads. Fig. 28C shows a bottom view (horizontal plane) of the inversion/ eversion flexibility design.

[0076] Fig. 29 illustrates in frontal plane cross section a significant element of the applicant's shoe design in its use of stabilizing quadrants 26 at the outer edge of a shoe sole 28b illustrated generally at the reference numeral 28. It is thus a main feature of the applicant's invention to eliminate the unnatural sharp bottom edge, especially of flared shoes, in favor of a rounded shoe sole edge 25 as shown in Fig. 29. The side or edge 25 of the shoe sole 28 is contoured much like the natural form on the side or edge of the human foot, but in a geometrically precise manner to follow a theoretically ideal stability plane. According to the invention, the thickness (s) of the shoe sole 28 is maintained exactly constant, even if the shoe sole is tilted to either side, or forward or backward. Thus, the side stabilizing quadrants 26, according to the applicant's invention, are defined by a radius 25a which is the same as the thickness 34 of the shoe sole 28b so that, in cross section, the shoe sole comprises a stable shoe sole 28 having at its outer edges quadrants 26 a surface 25 representing a portion of a theoretically ideal stability plane and described by a radius 25a equal to the thickness (s) of the sole and a quadrant center of rotation at the outer edge 41 at the top of the shoe sole 30b, which coincides with the shoe wearer's load-bearing footprint. An outer edge 32 of the quadrant 26 coincides with the horizontal plane of the top of the shoe sole 28b, while the other edge of the quadrant 26 is perpendicular to the edge 32 and coincides with the perpendicular sides 34 of the shoe sole 28b. In practice, the shoe sole 28 is preferably integrally formed from the portions 28b and 26. The outer edge 32 may also extend to lie at an angle relative to the sole upper surface. Thus, the theoretically ideal stability plane includes the contours 25 merging into the lower surface 31b of the sole 28b.

[0077] Preferably, the peripheral extent of the sole 36 of the shoe includes all of the support structures of the foot but extends no further than the outer edge of the foot sole 37 as defined by a load-bearing footprint, as shown in Fig. 4D, which is a top view of the upper shoe sole surface 30b. Fig. 4D thus illustrates a foot outline at numeral 37 and a recommended sole outline 36 relative thereto. Thus, a horizontal plane outline of the top of the shoe sole should, preferably, coincide as nearly as practicable with the load-bearing portion of the foot sole with which it comes into contact. Such a horizontal outline, as best seen in Fig. 4D, should remain uniform throughout the entire thickness of the shoe sole eliminating negative or positive sole flare so that the sides are exactly perpendicular to the horizontal plane as shown in Fig. 29B. Preferably, the density of the shoe sole material is uniform.

[0078] Another significant feature of the applicant's invention is illustrated diagrammatically in Fig. 30. Preferably, as the heel lift or wedge increases the thickness (s) of the shoe sole in an aft direction of the shoe, the side quadrants 26 increase about exactly the same amount according to the principles discussed in connection with Fig. 29. Thus, according to the applicant's design, the radius 25a of curvature (r) of the side quadrant is always equal to the constant thickness (s) of the shoe sole in the frontal cross sectional plane.

[0079] As shown in Fig. 30B, for a shoe that follows a more conventional horizontal plane outline, the sole can be improved significantly according to the applicant's invention by the addition of outer edge quadrant 26 having a radius which correspondingly varies with the thickness of the shoe sole and changes in the frontal plane according to the shoe heel lift. Thus, as illustrated in Fig. 30B, the radius of curvature of the quadrant 26a is equal to the thickness s1 of the shoe sole 28b which is thicker than the shoe sole (s) shown in Fig. 30A by an amount equivalent to the heel lift (s-s1). In the generalized case, the radius (r1) of the quadrant is thus always equal to the thickness (s) of the shoe sole.

[0080] Fig. 31 illustrates how the center of rotation of the quadrant sole side 41 is maintained at a constant distance (s) from the ground through various degrees of rotation of the edge 25 of the shoe sole, in contrast to Figure 10B. By remaining a constant distance from the ground, the stable shoe allows the foot to react to the ground as if the foot were bare while allowing the foot to be protected and cushioned by the shoe. In its preferred embodiment, the new contoured design assumes that the shoe uppers 21, including heel counters and other motion control devices, will effectively position and hold the foot onto the load-bearing foot print section of the shoe sole.

[0081] Fig. 32 illustrates an embodiment of the invention which utilizes only a portion of the theoretically ideal stability plane 51 in the quadrants 26 in order to reduce the weight and bulk of the sole, while accepting a sacrifice in some stability of the shoe. Thus, Fig. 32A illustrates the preferred embodiment as described above in connection with Fig. 30 wherein the outer quadrant 50 follows a theoretically ideal stability plane 51 about a center 52 and defines a surface 53 which is coplanar (or at an angle) with the upper surface of the shoe sole 54. As in Fig. 29, the contoured surfaces 50, and the lower surface of the sole 54A lie along the theoretically ideal stability plane. As shown in Fig. 32B, an engineering trade-off results in an abbreviation within the ideal stability plane 51 by forming a quadrant surface 53a at an angle relative to the upper plane of the shoe sole 54 so that only a portion of the quadrant defined by the radius lying along the surface 50a is coplanar with the theoretically ideal stability plane 51. Fig. 32C shows a similar embodiment wherein the engineering trade-off results in a portion 50b which lies along the theoretically ideal stability plane 51. The portion 50b merges into a second

portion 56 which itself merges into the upper surface 53a of the quadrant.

[0082] The embodiment of Fig. 32 may be desirable for portions of the shoe sole which are less frequently used so that the additional part of the side is used less frequently. For example, a shoe may typically roll out laterally, in an inversion mode, to about 20 degree on the order of 100 times for each single time it rolls out to 40 degree. Yet, the added shoe weight to cover that entire range is about equivalent to covering the limited range. Since in a racing shoe this weight might not be desirable, an engineering trade-off of the type shown in Fig. 32C is possible.

[0083] Fig. 33, in Figs. 33A-33C, shows a development of a street shoe with a contoured sole incorporating the features of the invention. Fig. 33A shows a heel cross section of a typical street shoe 94 having a sole portion 79 and a heel lift 81. Fig. 33B develops a theoretically ideal stability plane 51, as described above, for such a street shoe, wherein the radius (r) of curvature of the sole edge is equal to the shoe sole thickness. The resulting street shoe with a correctly contoured sole is thus shown in Fig. 33C, with a reduced side edge thickness for a less bulky and more aesthetically pleasing look. Accordingly, the invention can be applied to an unconventional heel lift shoe, like a simple wedge, or to the most conventional design of a typical walking shoe with its heel separated from the forefoot by a hollow under the instep. For the embodiment of Fig. 33, the theoretically ideal stability plane is determined by the shoe sole width and thickness, using an optimal human heel width as measured along the width of the hard human heel tissue on which the heel is assumed to rotate in an inversion/eversion mode. With the invention, as so applied, the stability and natural motion of any existing shoe design, except high heels or spike heels, can be significantly improved by contouring the bottom sole to the theoretically ideal stability plane.

[0084] Figs. 34A and 34B show the possible desirability of using wedge inserts 84 with the sole of the invention to support the calcaneal tuberosity. As seen in Fig. 34A, the calcaneal tuberosity 99 is unsupported when a shoe of the prior art is inverted through an angle of 20 degrees. This is about the natural extreme limit of calcaneal inversion motion at which point the calcaneal tuberosity, located on the lateral side of the calcaneus, makes contact with the ground and restricts further lateral motion. When the conventional wide shoe sole reaches such an inversion limit, the sole leaves the calcaneal tuberosity 99 completely unsupported in the area 100, whereas when the foot is bare, the calcaneal tuberosity contacts the ground, providing a firm base of support. To address this situation, a wedge 84 of a relatively firm material, usually roughly equivalent to the density of the midsole and the heel lift, is located on top of the shoe sole under the insole in the lateral heel area to support the lateral calcaneal tuberosity. Thus, such a wedge support can also be used with the sole of the invention as shown in Fig. 34B. Usually, such a wedge will taper toward the front of the shoe and is contoured to the shape of the calcaneus and its tuberosity. If preferred, the wedge can be integrated with and be a part of a typical contoured heel of an insole.

[0085] The shoe sole according to the invention can be made by approximating the contours, as indicated in Figs. 35 and 36. In the proposed approximation as seen in Fig. 35, the heel cross section includes a sole upper surface 101 and a sole edge surface 104 following the theoretically ideal stability plane 51. The sole edge surface 104 terminates in a laterally extending portion 105 joined to the heel 106. The laterally-extending portion 105 is made from a flexible material and structured to cause its lower surface 105a to terminate during deformation at the theoretically ideal stability plane. Thus, in a dynamic case, the outer edge contour assumes approximately the shape described above as a result of the deformation of the portion 105.

[0086] It is presently contemplated that the controlled or programmed deformation can be provided by either of two techniques. In one, the shoe sole sides, at especially the midsole, can be cut in a tapered fashion or grooved so that the bottom sole bends inwardly under pressure to the correct contour. The second uses an easily deformable material in a tapered manner on the sides to deform under pressure to the correct contour. While such techniques produce stability and natural motion results which are a significant improvement over conventional designs, they are inherently inferior to contours produced by simple geometric shaping. First, the actual deformation must be produced by pressure which is unnatural and does not occur with a bare foot and second, only approximations are possible by deformation, even with sophisticated design and manufacturing techniques, given an individual's particular running gait or body weight. Thus, the deformation process is limited to a minor effort to correct the contours from surfaces approximating the ideal curve in the first instance.

[0087] The theoretically ideal stability curve 51 can also be approximated by a plurality of line segments 110, such as tangents or chords, shown in Fig. 36. While a single flat plane approximation may correct many of the biomechanical problems occurring with existing designs, because it removes most the area outside of the theoretically ideal stability plane 51, the single plane approximation is presently not preferred, since it is the least optimal. By increasing the number of flat planar surfaces formed, the curve more closely approximates exactly the ideal design contour, as previously described.

[0088] Fig. 37 shows in frontal plane cross section the essential concept underlying this invention, the theoretically ideal stability plane, which is also theoretically ideal for efficient natural motion of all kinds, including running, jogging or walking.

[0089] For any particular individual (or size average of individuals), the theoretically ideal stability plane is

determined, first, by the given shoe sole thickness (s), and, second, by the frontal plane cross section width of the individual's load-bearing footprint 30b, which is defined as the upper surface of the shoe sole that is in physical contact with and supports the human foot sole.

[0090] The theoretically ideal stability plane is composed conceptionally of two parts. The first part is a line segment 31b of equal length and parallel to 30b at a constant distance (s) equal to shoe sole thickness. This corresponds to a conventional shoe sole directly underneath the human foot. The second part is a quadrant edge 25 or quarter of a circle (which may be extended up to a half circle) at each side of the first part, line segment 31b. The quadrant edge 25 is at radius (r), which is equal to shoe sole thickness (s), from a center of rotation 41, which is the outermost point on each side of the line segment 30b. In summary, the theoretically ideal stability plane is the essence of this invention because it is used to determine a geometrically precise bottom contour of the shoe sole. And, this invention specifically claims the exactly determined geometric relationship just described. It can be stated unequivocally that any shoe sole contour, even of similar quadrant contour, that exceeds the theoretically ideal stability plane will restrict natural foot motion, while any lesser contour will degrade natural stability.

[0091] That said, it is possible that an adjustment to a definition included in the preceding conception might be made at some point in the future not on a theoretical basis, but an empirical one. It is conceivable that, in contrast to the rest of the foot, a definition of line segment 30b at the base of the human heel could be the width of the very hard tissue (bone, cartilage, etc.), instead of the load-bearing footprint, since it is possible that the heel width is the geometrically effective pivoting width which the shoe heel must precisely equal in order to pivot optimally with the human heel. For a typical male size 10D, that very hard tissue heel width is 1.75 inches, versus 2.25 inches for the load-bearing footprint of the heel. Though not optimal, narrower heel width 30b assumptions, even much narrower, may be used in non-athletic street shoes to obtain a significant proportion of the increases in stability and efficiency provided by the invention, while retaining a more traditional appearance, especially with higher heeled shoes.

[0092] It is an empirical question, though, not a question of theoretical framework. Until more empirical work is done, optimal heel width must be based on assumption. The optimal width of the human heel pivot is, however, a scientific question to be determined empirically if it can be, not a change in the essential theoretically ideal stability plane concept claimed in the invention. Moreover, the more narrow the definition, the more important exact fit becomes and relatively minor individual misalignments could produce pronation control problems, for example, that negate any possible advantage.

[0093] Fig. 38 shows a non-optimal but interim or low cost approach to shoe sole construction, whereby the midsole and heel lift 127 are produced conventionally, or nearly so (at least leaving the midsole bottom surface flat, though the sides can be contoured), while the bottom or outer sole 128 includes most or all of the special contours of the new design. Not only would that completely or mostly limit the special contours to the bottom sole, which would be molded specially, it would also ease assembly, since two flat surfaces of the bottom of the midsole and the top of the bottom sole could be mated together with less difficulty than two contoured surfaces, as would be the case otherwise. The advantage of this approach is seen in the naturally contoured design example illustrated in Fig. 38A, which shows some contours on the relatively softer midsole sides, which are subject to less wear but benefit from greater traction for stability and ease of deformation, while the relatively harder contoured bottom sole provides good wear for the load-bearing areas. Fig. 38B shows in a quadrant side design the concept applied to conventional street shoe heels, which are usually separated from the forefoot by a hollow instep area under the main longitudinal arch. Fig. 38C shows in frontal plane cross section the concept applied to the quadrant sided or single plane design and indicating in Fig. 38D in the shaded area 129 of the bottom sole that portion which should be honeycombed (axis on the horizontal plane) to reduce the density of the relatively hard outer sole to that of the midsole material to provide for relatively uniform shoe density. Fig. 38E shows in bottom view the outline of a bottom sole 128 made from flat material which can be conformed topologically to a contoured midsole of either the one or two plane designs by limiting the side areas to be mated to the essential support areas discussed in Fig. 21; by that method, the contoured midsole and flat bottom sole surfaces can be made to join satisfactorily by coinciding closely, which would be topologically impossible if all of the side areas were retained on the bottom sole.

[0094] Figs. 39A-39C, frontal plane cross sections, show an enhancement to the previously described embodiments of the shoe sole side stability quadrant invention. As stated earlier, one major purpose of that design is to allow the shoe sole to pivot easily from side to side with the foot 90, thereby following the foot's natural inversion and eversion motion; in conventional designs shown in Fig. 39a, such foot motion is forced to occur within the shoe upper 21, which resists the motion. The enhancement is to position exactly and stabilize the foot, especially the heel, relative to the preferred embodiment of the shoe sole; doing so facilitates the shoe sole's responsiveness in following the foot's natural motion. Correct positioning is essential to the invention, especially when the very narrow or "hard tissue" definition of heel width is used. Incorrect or shifting relative position will reduce the inherent efficiency and stability of the side quadrant design, by reducing the effective thickness of the quadrant side 26 to less than that of the shoe sole 28b. As shown in Fig. 39B and 39C, naturally contoured

inner stability sides 131 hold the pivoting edge 31 of the load-bearing foot sole in the correct position for direct contact with the flat upper surface of the conventional shoe sole 22, so that the shoe sole thickness (s) is maintained at a constant thickness (s) in the stability quadrant sides 26 when the shoe is everted or inverted, following the theoretically ideal stability plane 51.

[0095] The form of the enhancement is inner shoe sole stability sides 131 that follow the natural contour of the sides 91 of the heel of the foot 90, thereby cupping the heel of the foot. The inner stability sides 131 can be located directly on the top surface of the shoe sole and heel contour, or directly under the shoe insole (or integral to it), or somewhere in between. The inner stability sides are similar in structure to heel cups integrated in insoles currently in common use, but differ because of its material density, which can be relatively firm like the typical mid-sole, not soft like the insole. The difference is that because of their higher relative density, preferably like that of the uppermost midsole, the inner stability sides function as part of the shoe sole, which provides structural support to the foot, not just gentle cushioning and abrasion protection of a shoe insole. In the broadest sense, though, insoles should be considered structurally and functionally as part of the shoe sole, as should any shoe material between foot and ground, like the bottom of the shoe upper in a slip-lasted shoe or the board in a board-lasted shoe.

[0096] The inner stability side enhancement is particularly useful in converting existing conventional shoe sole design embodiments 22, as constructed within prior art, to an effective embodiment of the side stability quadrant 26 invention. This feature is important in constructing prototypes and initial production of the invention, as well as an ongoing method of low cost production, since such production would be very close to existing art.

[0097] The inner stability sides enhancement is most essential in cupping the sides and back of the heel of the foot and therefore is essential on the upper edge of the heel of the shoe sole 27, but may also be extended around all or any portion of the remaining shoe sole upper edge. The size of the inner stability sides should, however, taper down in proportion to any reduction in shoe sole thickness in the sagittal plane.

[0098] Figs. 40A-40C, frontal plane cross sections, illustrate the same inner shoe sole stability sides enhancement as it applies to the previously described embodiments of the naturally contoured sides design. The enhancement positions and stabilizes the foot relative to the shoe sole, and maintains the constant shoe sole thickness (s) of the naturally contoured sides 28a design, as shown in Figs. 40B and 40C; Fig. 40A shows a conventional design. The inner shoe sole stability sides 131 conform to the natural contour of the foot sides 29, which determine the theoretically ideal stability plane 51 for the shoe sole thickness (s). The other features of the enhancement as it applies to the naturally contoured shoe sole sides embodiment 28 are the same as described previously under Figs. 39A-39C for the side stability quadrant embodiment. It is clear from comparing Figs. 40C and 39C that the two different approaches, that with quadrant sides and that with naturally contoured sides, can yield some similar resulting shoe sole embodiments through the use of inner stability sides 131. In essence, both approaches provide a low cost or interim method of adapting existing conventional "flat sheet" shoe manufacturing to the naturally contoured design described in previous figures.

[0099] Thus, it will clearly be understood by those skilled in the art that the foregoing description has been made in terms of the preferred embodiment and various changes and modifications may be made without departing from the scope of the present invention which is to be defined by the appended claims.

Claims

1. A shoe sole (28) for a shoe, the shoe sole (28) including:

   a sole lateral side, a sole medial side and a sole middle portion located between the sole lateral side and the sole medial side;
   a bottom sole (128);
   a midsole (127) which is softer than the bottom sole (128);
   an inner surface (30) having at least a portion that is concavely rounded relative to an intended wearer's foot location inside the shoe, as viewed in a frontal plane cross-section when the shoe sole (28) is in an upright, unloaded condition;
   the midsole (127) having an uppermost part which extends to at least the height of the lowest point of the inner surface (30), as viewed in a frontal plane cross-section when the shoe sole (28) is in an upright, unloaded condition;
   characterized in that:
   the outer surface (31) of the sole middle portion includes at least one concavely rounded portion which extends through the lowest point of the shoe sole (28), the concavity of the concavely rounded portion is determined relative to an intended wearer's foot location inside the shoe, as viewed in a frontal plane cross-section, when the shoe sole (28) is in an upright, unloaded condition.

2. A shoe sole (28) for a shoe as claimed in claim 1, wherein the at least one concavely rounded portion of the outer surface (31) extends to one or more locations on the shoe sole (28) proximate to the locations of one or more of the following parts of an intended wearer's foot when inside the shoe: the base of the calcaneus (95), the lateral tuberosity of the

calcaneus (95), the base of the fifth metatarsal (97), the head of the fifth metatarsal (96), the head of the first metatarsal (96), and the head of the first distal phalange (98).

3. The shoe sole (28) of any one of claims 1-2, wherein:

   at least a part of a bottom surface of the midsole (127) and at least a part of a top surface of the bottom sole (128) are substantially flat, as viewed in the frontal plane cross-section when the shoe sole (28) is in an upright, unloaded condition.

4. The shoe sole (28) of any one of claims 1-3, wherein the shoe sole (28) includes at least two concavely rounded portions of the outer surface (31) of the shoe sole (28), as viewed in a frontal plane cross-section when the shoe sole (28) is in an upright, unloaded condition.

5. The shoe sole (28) of any one of claims 1-4, wherein the frontal plane cross-section is located in the heel area.

6. The shoe sole (28) of any one of claims 1-5, wherein the thickness of a side portion of the shoe sole (28) which is located in the same frontal plane cross-section as the concavely rounded portion of the outer surface (31) decreases gradually in at least one of an anterior direction and a posterior direction to a lesser thickness, as viewed in a horizontal plane, to thereby provide torsional flexibility and weight savings to the shoe sole (28).

7. A shoe sole (28) as claimed in claim 6, wherein the thickness of the portion of the shoe sole (28) which has a concavely rounded portion of the outer surface (31) decreases gradually in both an anterior direction and a posterior direction, as viewed in a horizontal plane.

8. The shoe sole (28) of any one of claims 1-7, wherein:

   the upper surface of a side portion of the bottom sole (128) is substantially flat, as viewed in a frontal plane cross-section when the shoe sole (28) is in an upright, unloaded condition.

9. The shoe sole (28) of any one of claims 1-8, including a combined midsole and lift (127) and wherein the thickness of the midsole and lift (127) of a portion of the shoe sole (28) having a concavely rounded portion of the outer surface (31), as measured in a first frontal plane cross-section when the shoe sole (28) is in an upright, unloaded condition, is greater than the thickness of the midsole and lift (127) of a different sole portion which does not have a concavely rounded outer surface portion, as measured in a second frontal plane cross-section, when the shoe sole (28) is in an upright, unloaded condition.

10. The shoe sole (28) as claimed in claim 9, wherein the thickness of the midsole and lift (127) is defined as the distance between any point on a top surface of the combined midsole and lift (127) and the closest point on a bottom surface of the midsole and lift (127), as viewed in a frontal plane cross-section when the shoe sole (28) is in an upright, unloaded condition.

11. The shoe sole (28) of any one of claims 9-10, wherein the lift is a heel lift (127).

12. The shoe sole (28) of any one of claims 1-11, wherein the portion of the shoe sole (28) with a concavely rounded outer surface (31) has a thickness which decreases gradually through successive, adjacent frontal plane cross-sections to thereby increase the torsional flexibility of the shoe sole (28), when the shoe sole (28) is in an upright, unloaded condition.

13. The shoe sole (28) of any one of claims 1-12, wherein the outer surface (31) forms an arc of more than 90° from the concavely rounded portion to an uppermost part, as viewed in a frontal plane cross-section when the shoe sole (28) is in an upright, unloaded condition.

14. The shoe sole (28) of any one of claims 1-13, wherein the portion of the shoe sole (28) which has a concavely rounded outer surface (31) further includes an area of increased material density to form a structural support or propulsion element for the foot (27) of an intended wearer.

15. The shoe sole (28) of any one of claims 1-13, wherein the portion of the shoe sole (28) which has a concavely rounded outer surface (31) further includes an area of increased material firmness to form a structural support or propulsion element for the foot (27) of an intended wearer.

16. The shoe sole (28) of any one of claims 1-15, wherein the concavely rounded portion of the inner surface (30) extends substantially to a sidemost extent of the inner surface (30), as viewed in a frontal plane cross-section when the shoe sole is in an upright, unloaded condition.

17. A shoe sole as claimed in any one of claims 1-16, wherein an inner surface of the midsole conforms to the shape of an intended wearer's foot when inside the shoe.

FIG. 1
(PRIOR ART)

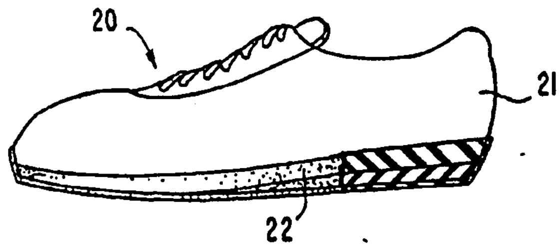


FIG. 2A
(PRIOR ART)

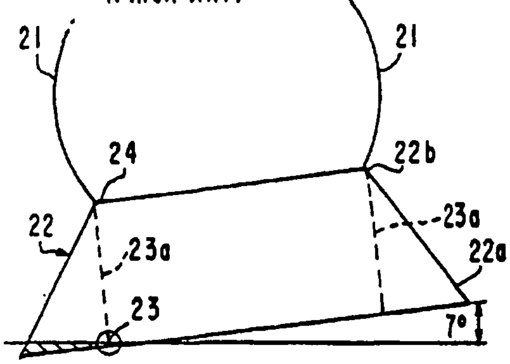


FIG. 2

FIG. 2B
(PRIOR ART)

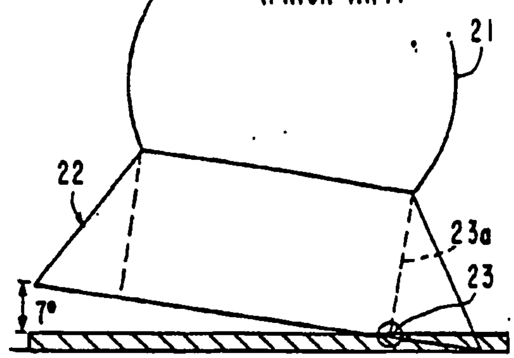


FIG. 2C

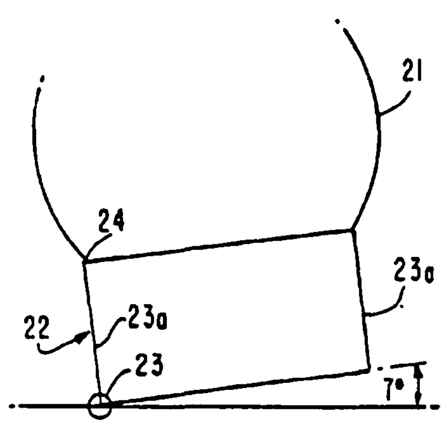


FIG. 2D

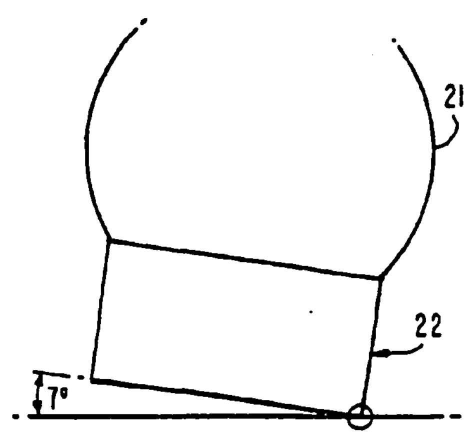


FIG. 3

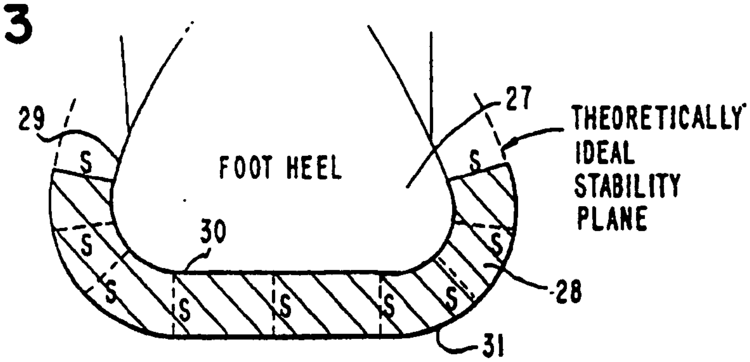


FIG. 4

FIG. 4A

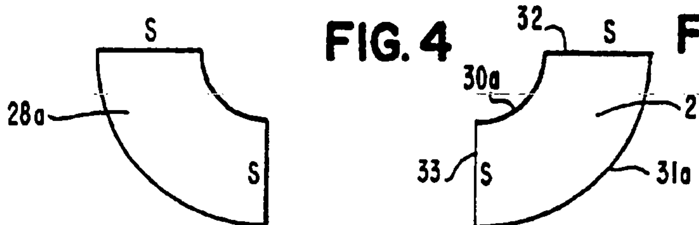


FIG. 4B

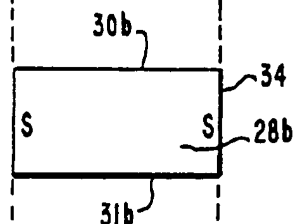


FIG. 4C

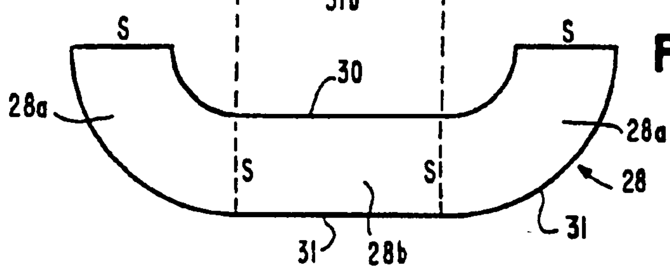


FIG. 4D

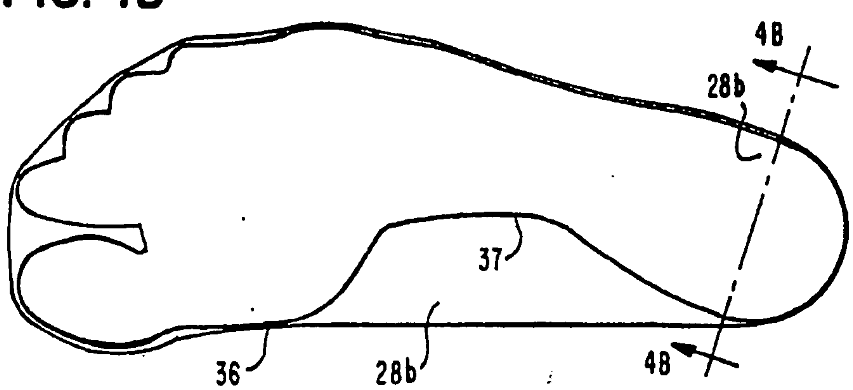


FIG. 5

FIG. 5A

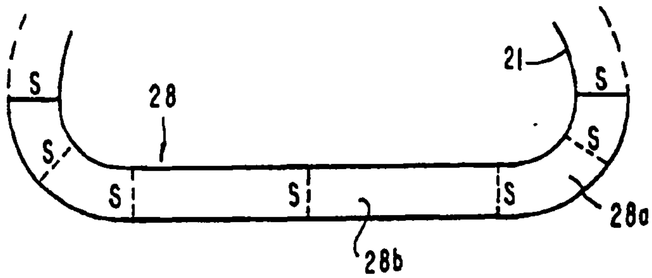


FIG. 5B

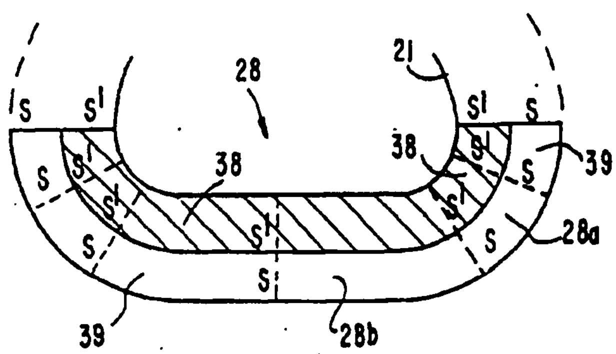


FIG. 6

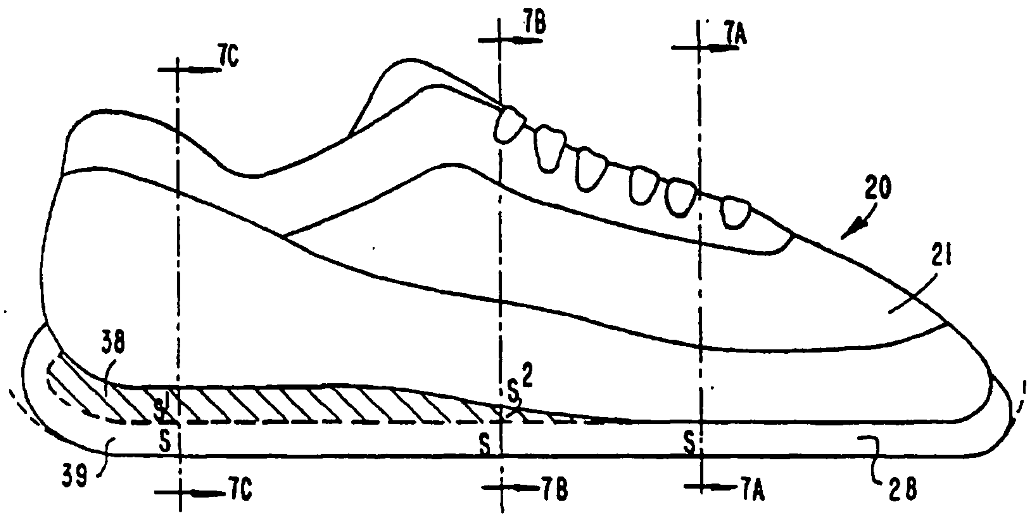


FIG. 7A

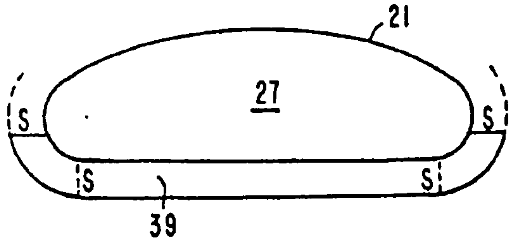


FIG.7B

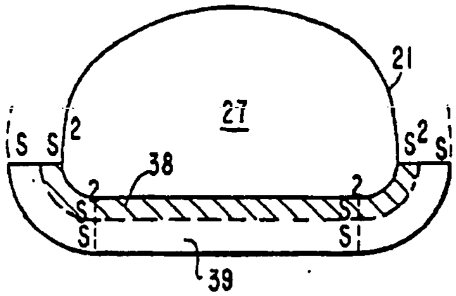


FIG. 7C

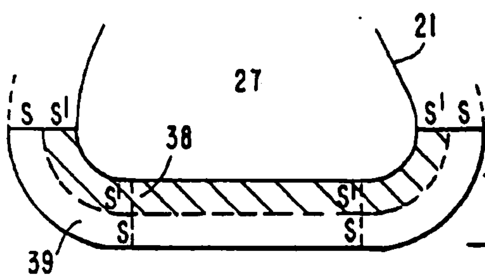


FIG. 7

FIG.7D

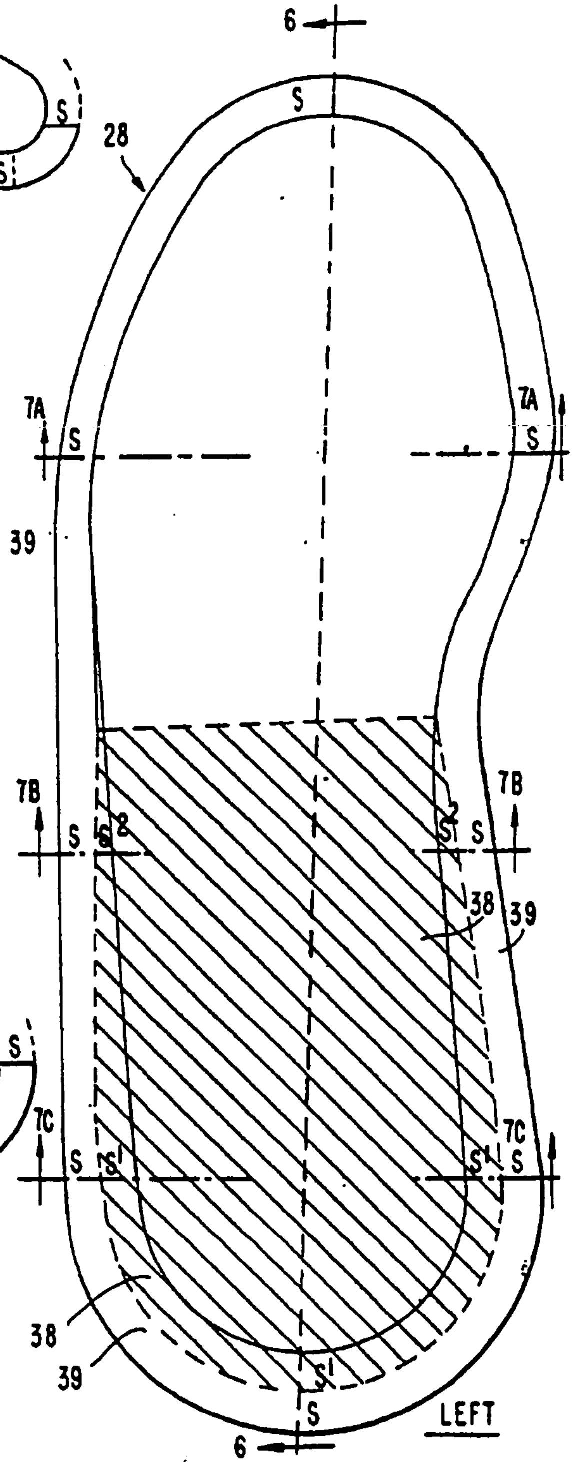


FIG. 8

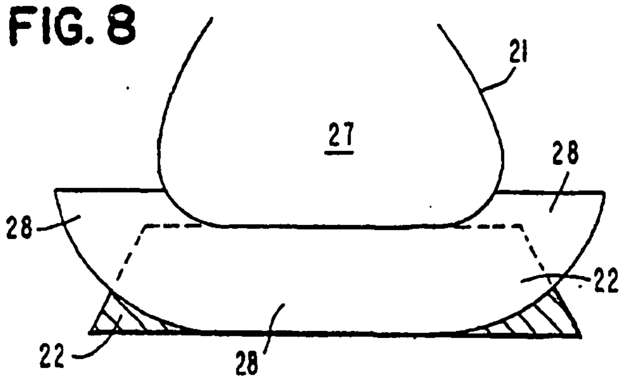


FIG. 9

FIG. 9A

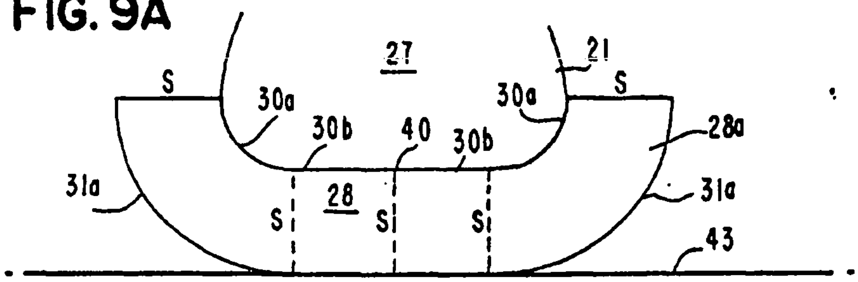


FIG. 9B

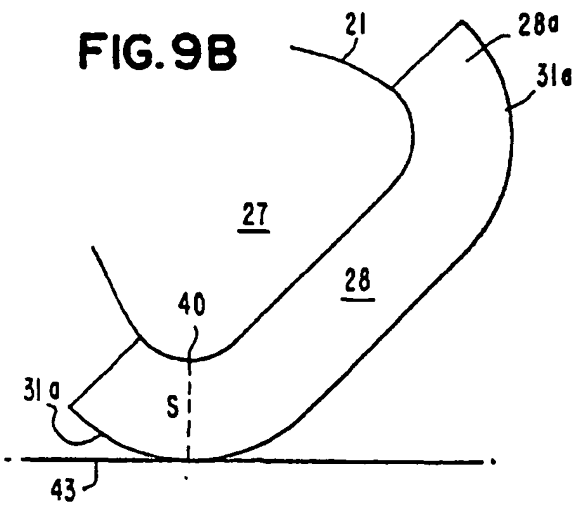
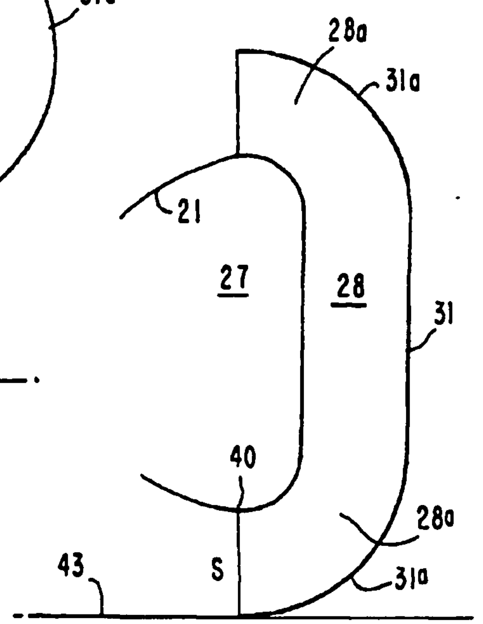


FIG. 9C



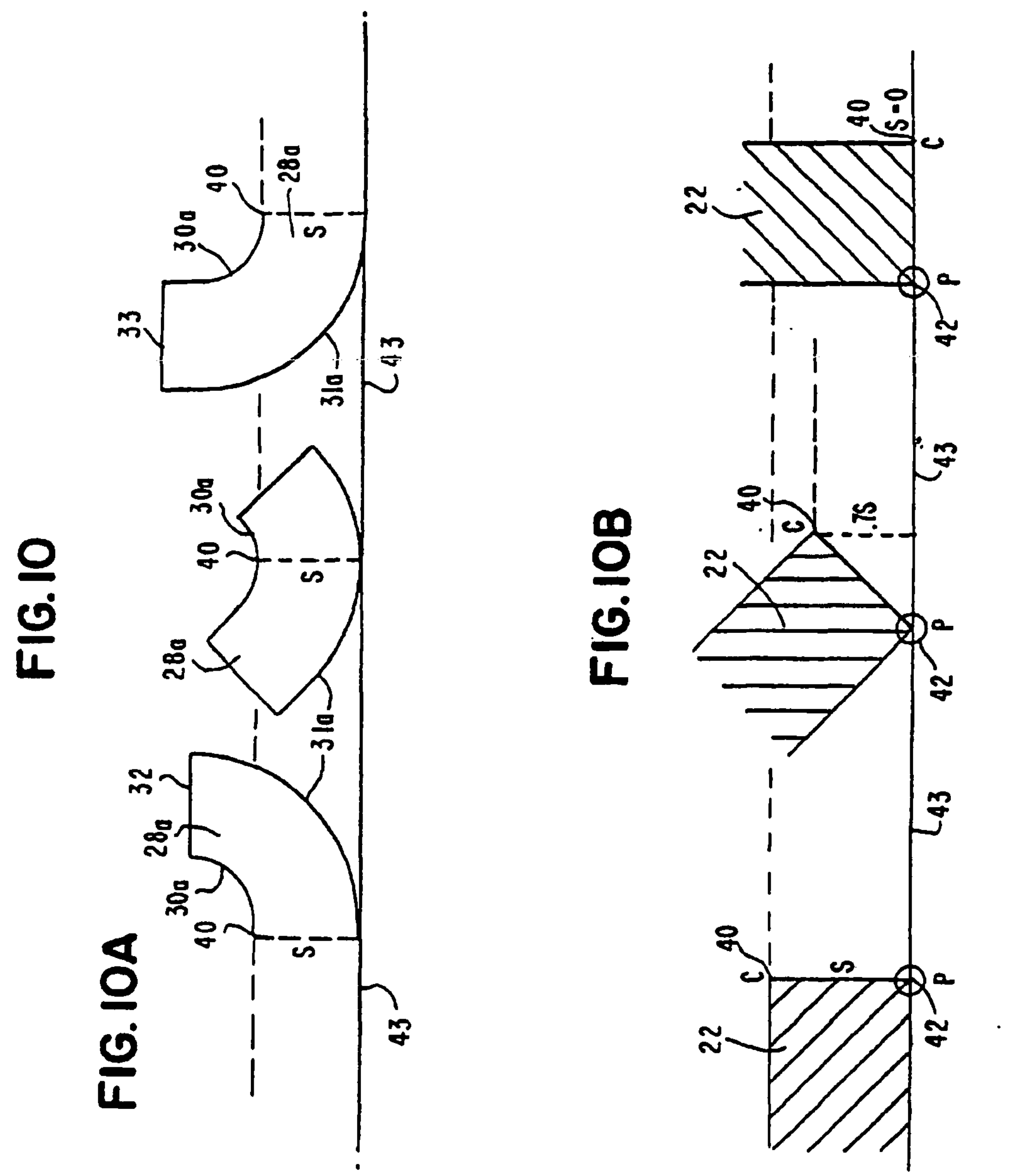


FIG.10

FIG.10A

FIG.10B

FIG.11

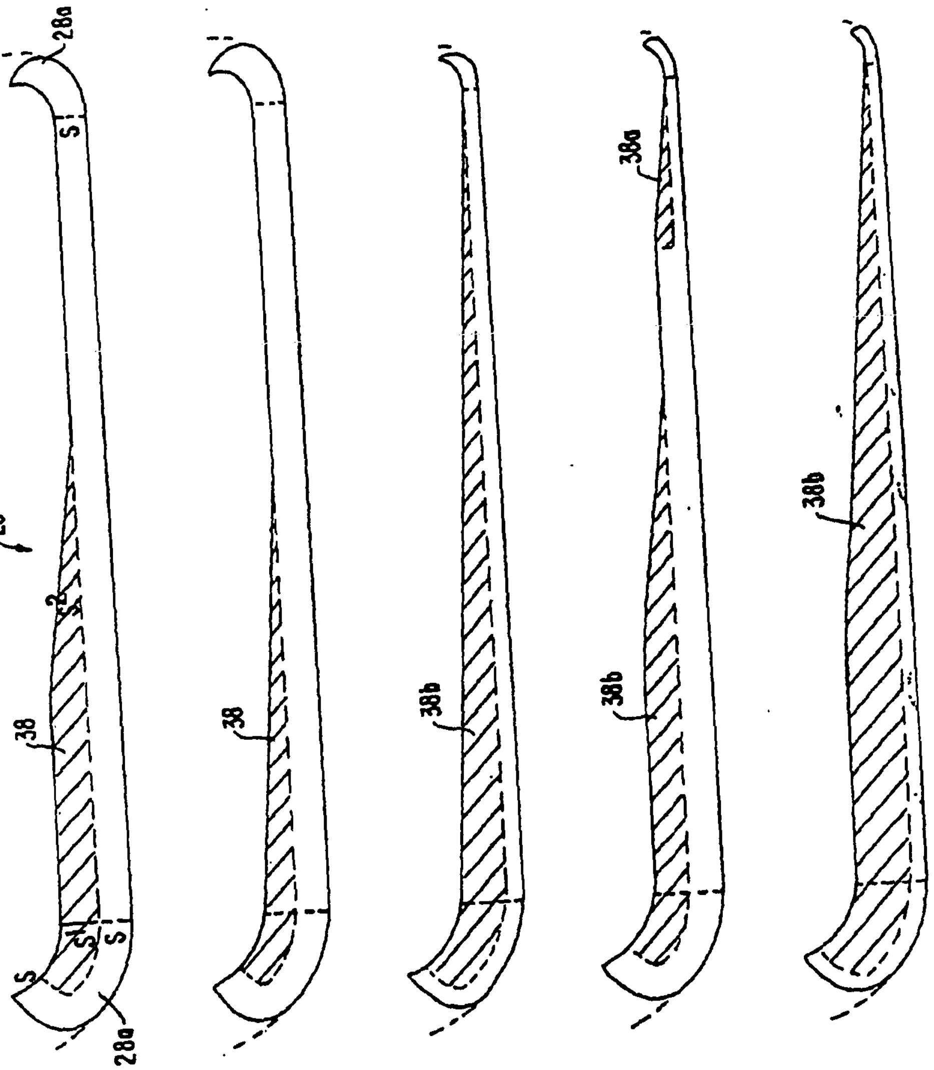


FIG.11A

FIG.11B

FIG.11C

FIG.11D

FIG.11E

FIG. 12

FIG. 12A

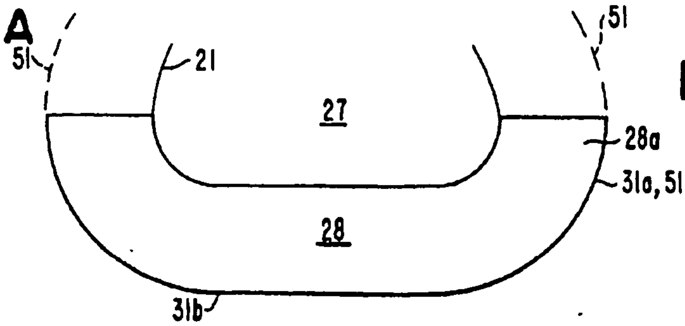


FIG. 12B

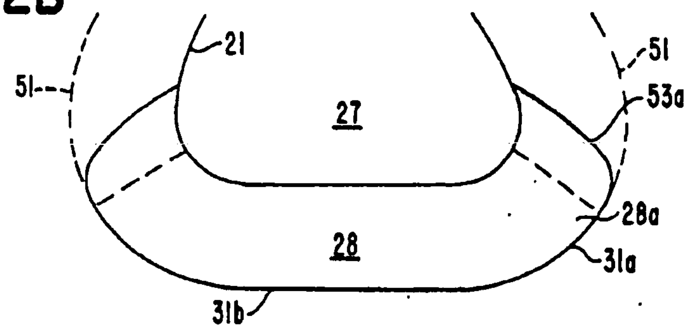


FIG. 12C

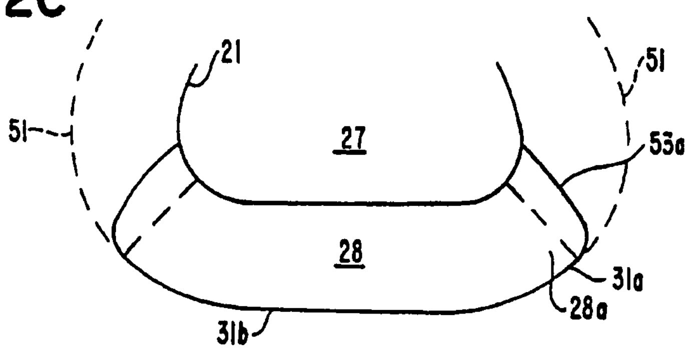


FIG. 12D

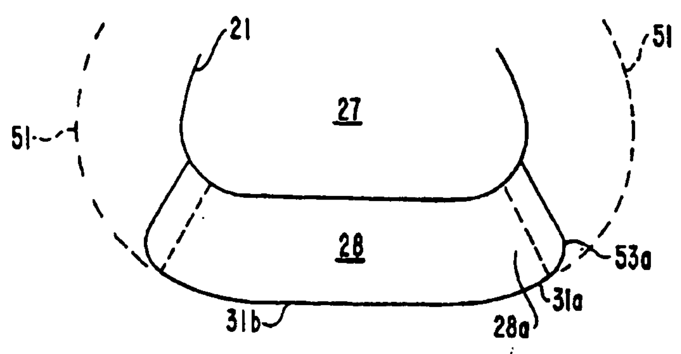


FIG. 13

FIG. 13A

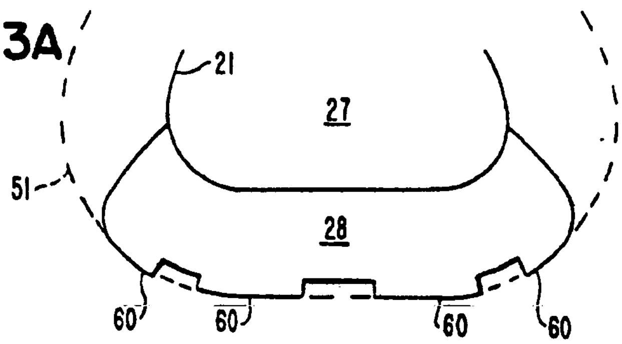


FIG. 13B

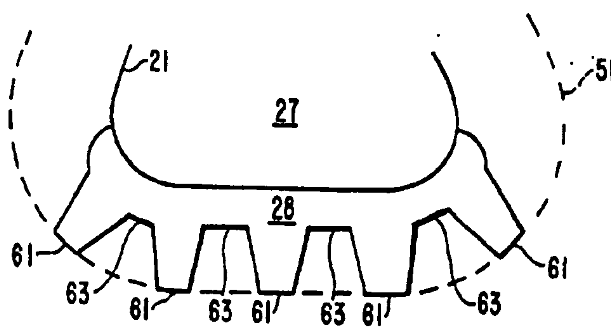


FIG. 13C

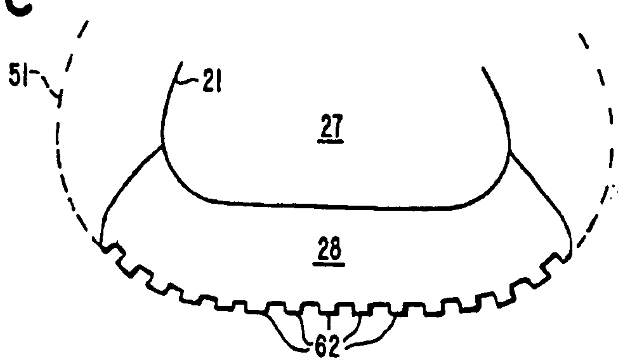


FIG. 14

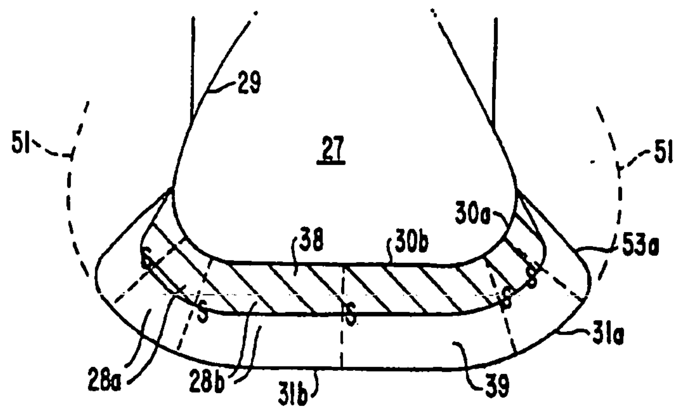

29
27
51
51
30a
38
30b
53a
S
S
S
S
S
31a
28a
28b
31b
39

FIG. 15

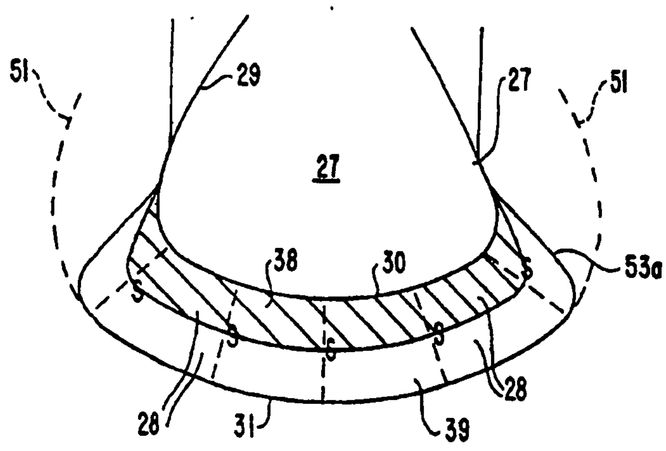

51
29
27
27
51
38
30
53a
S
S
S
S
S
28
28
31
39

FIG. 16

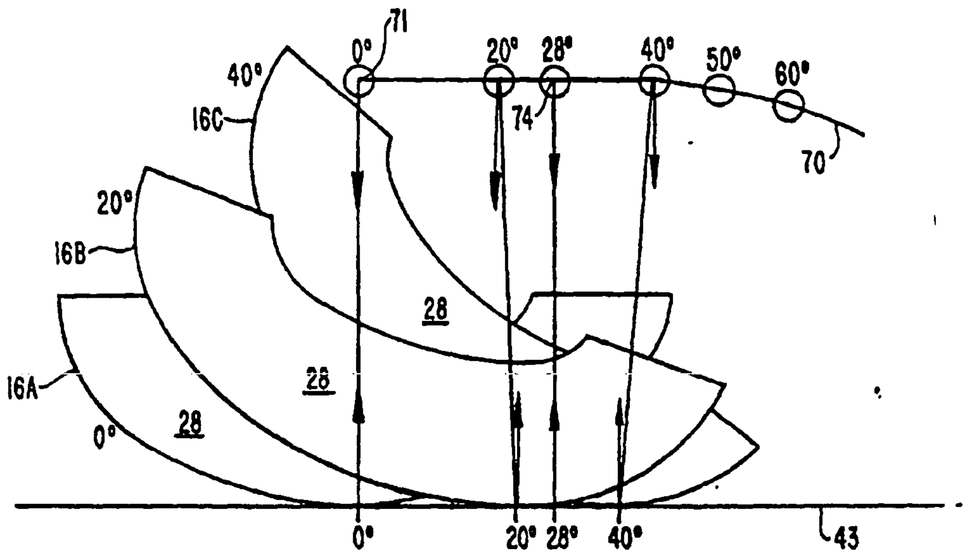

71
0°
20°
28°
40°
50°
60°
40°
16C
74
70
20°
16B
28
16A
28
0°
28
0°
20°
28°
40°
43

FIG. 17

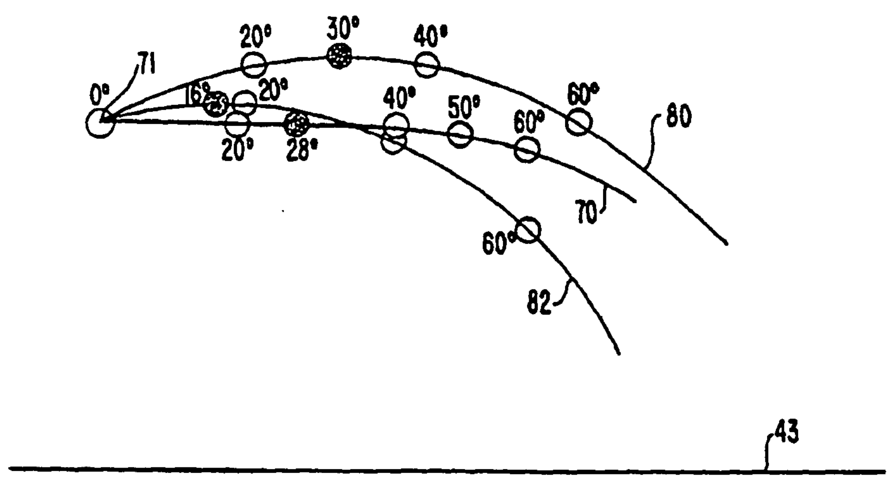

20°
30°
40°
0°
71
162
20°
40°
50°
60°
60°
80
20°
28°
70
60°
82
43

FIG. 18

FIG. 18A

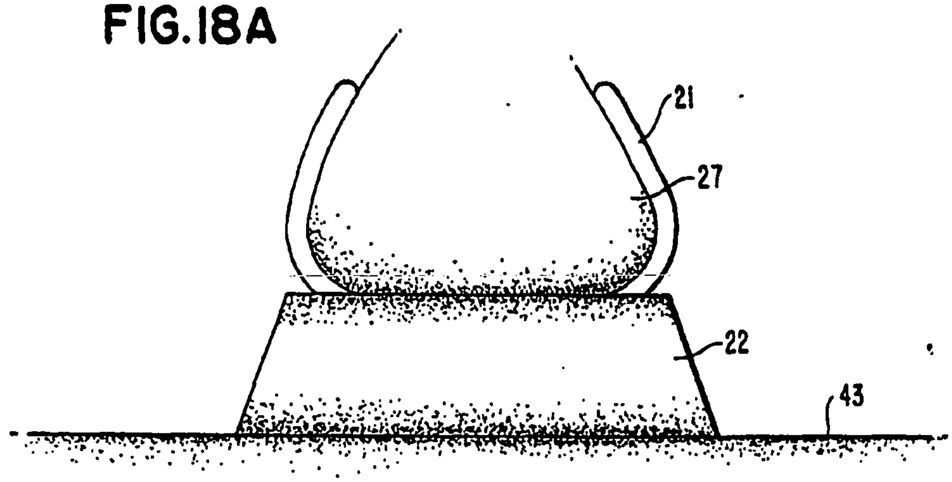


FIG. 18B

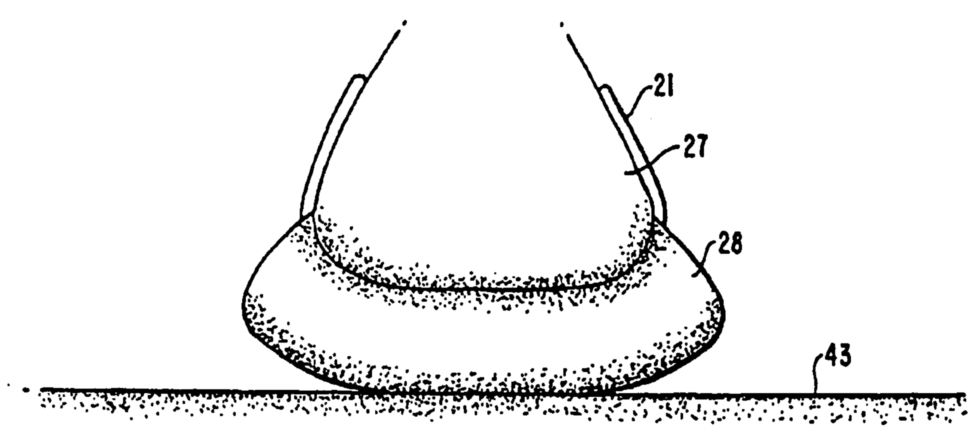


FIG. 19A

FIG. 19

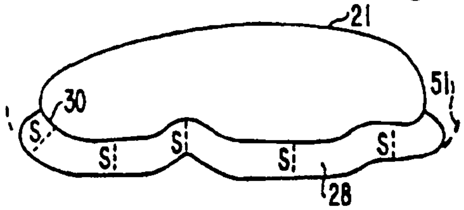


FIG. 19F

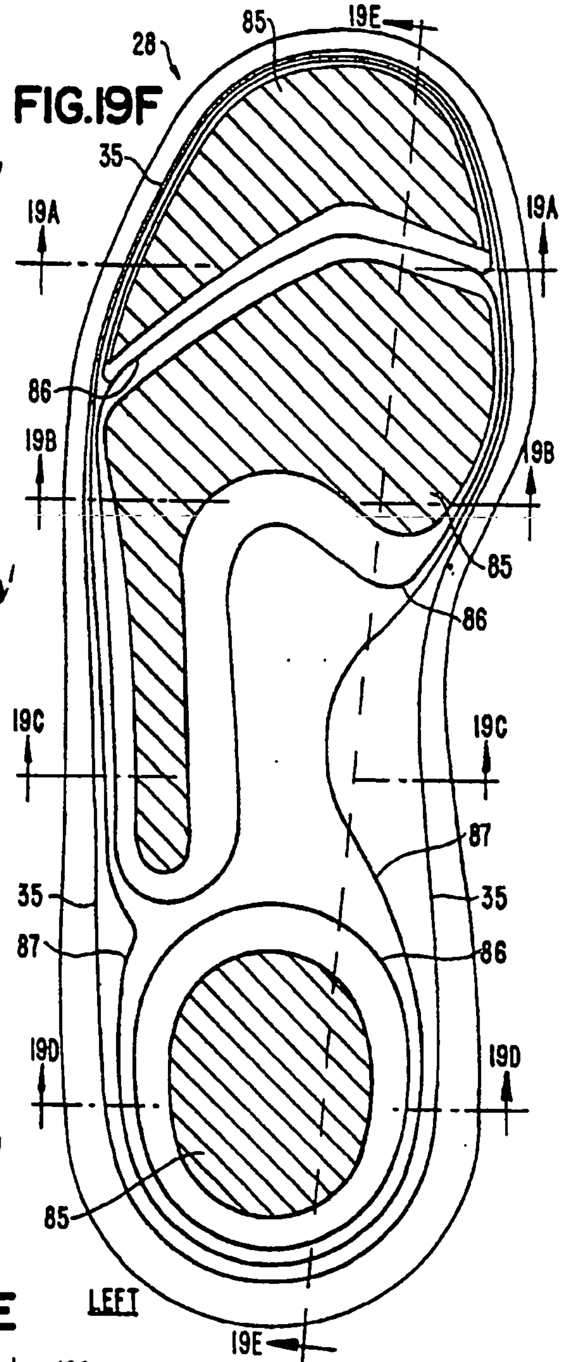


FIG. 19B

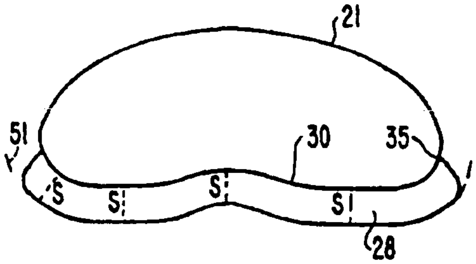


FIG. 19C

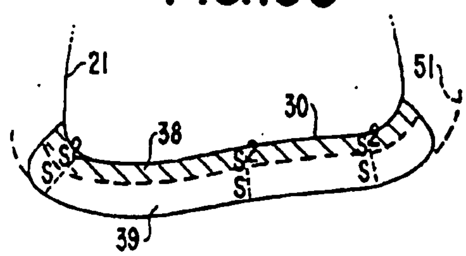


FIG. 19D

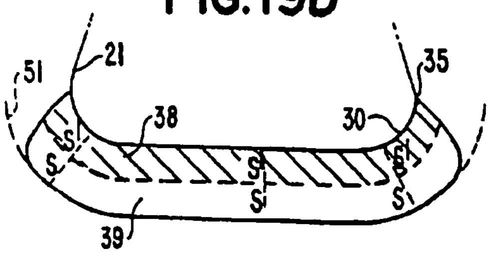


FIG. 19E

LEFT

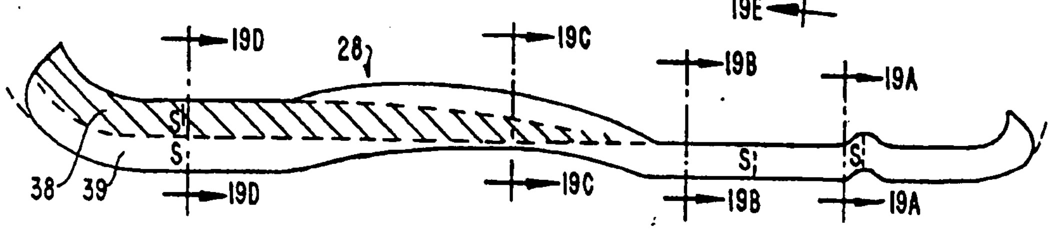


FIG. 20A

FIG. 20

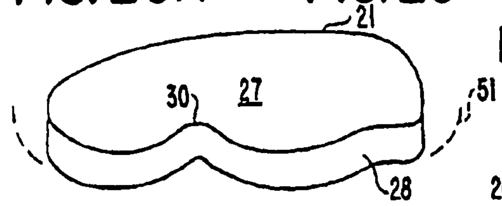


FIG. 20B

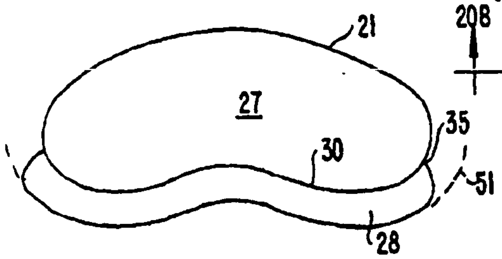


FIG. 20C

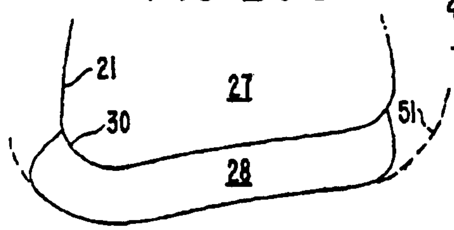


FIG. 20D

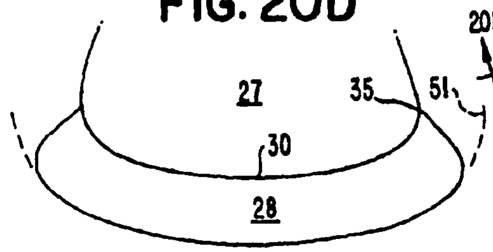


FIG. 21

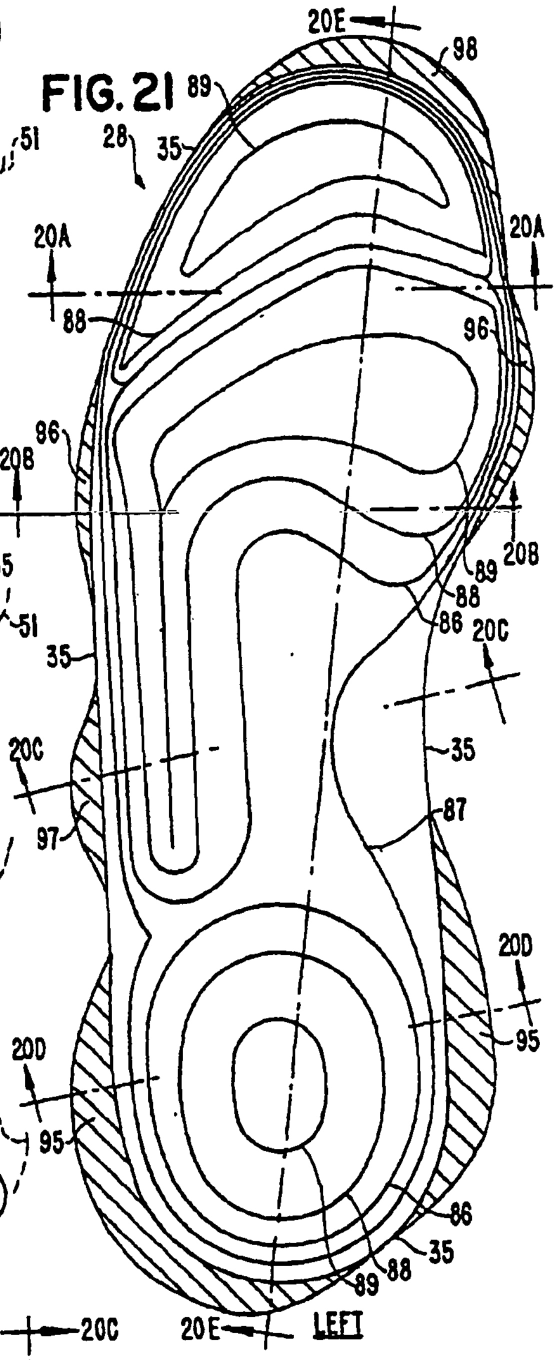


FIG. 20E

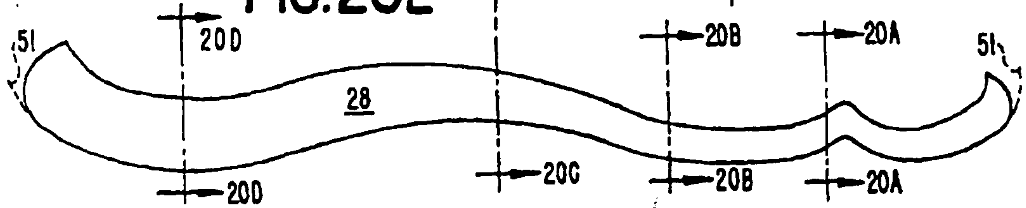


FIG. 22

FIG. 22A

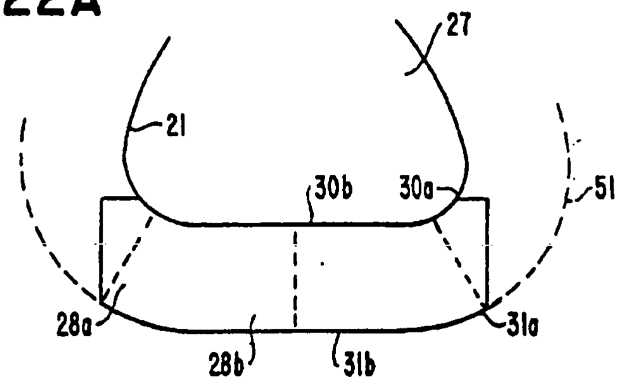


FIG. 22B

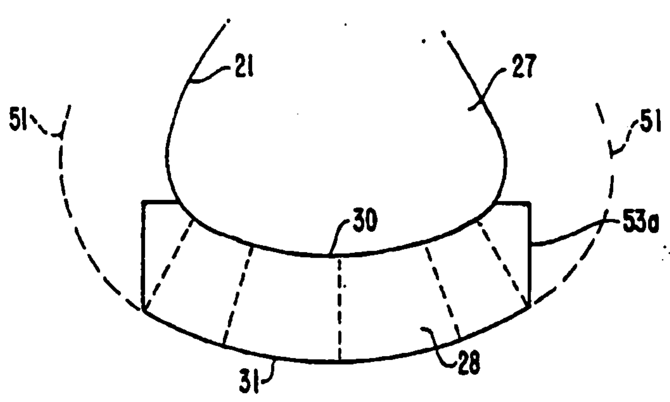


FIG. 23

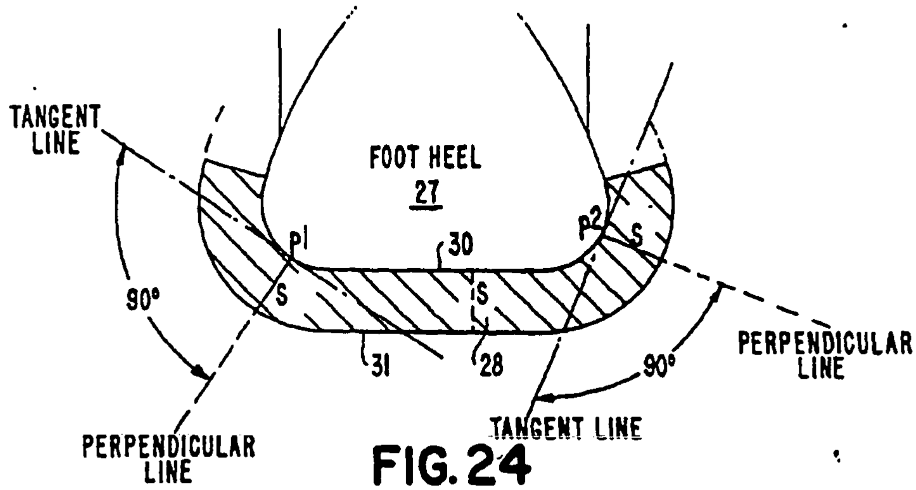


FIG. 24

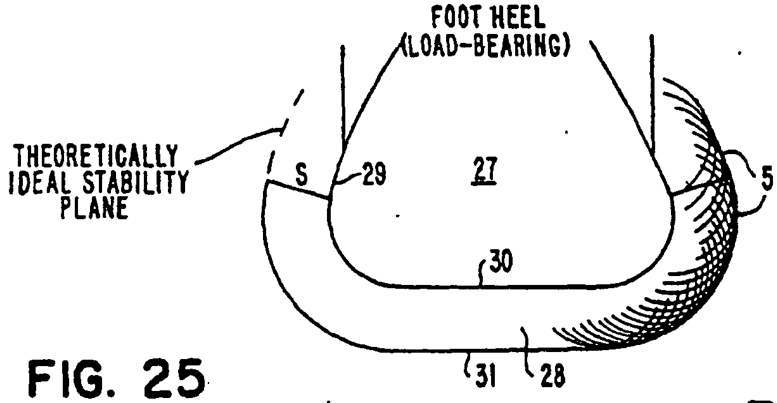


FIG. 25

FIG. 25A

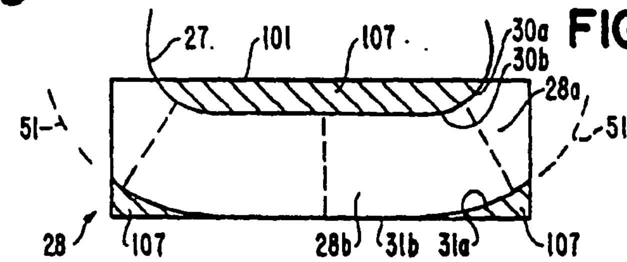


FIG. 25B

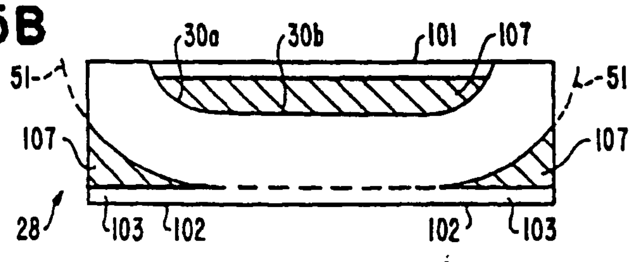


FIG.26

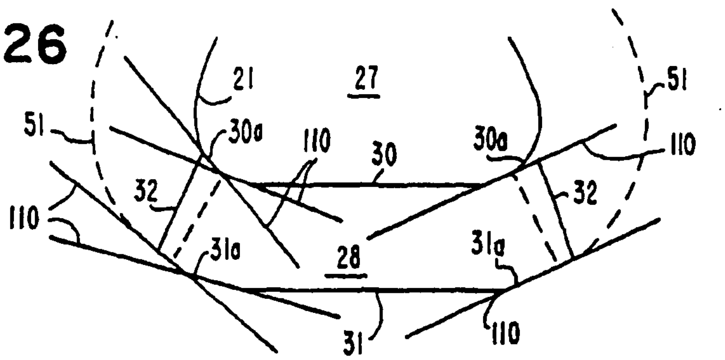


FIG. 27

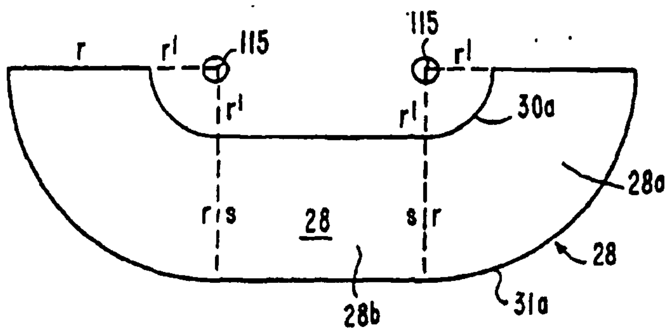


FIG. 28A

FIG. 28

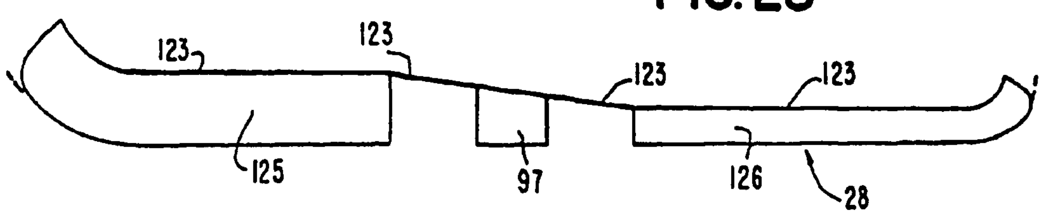


FIG. 28B

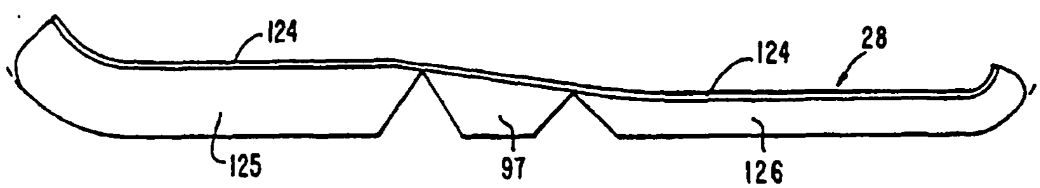


FIG. 28C

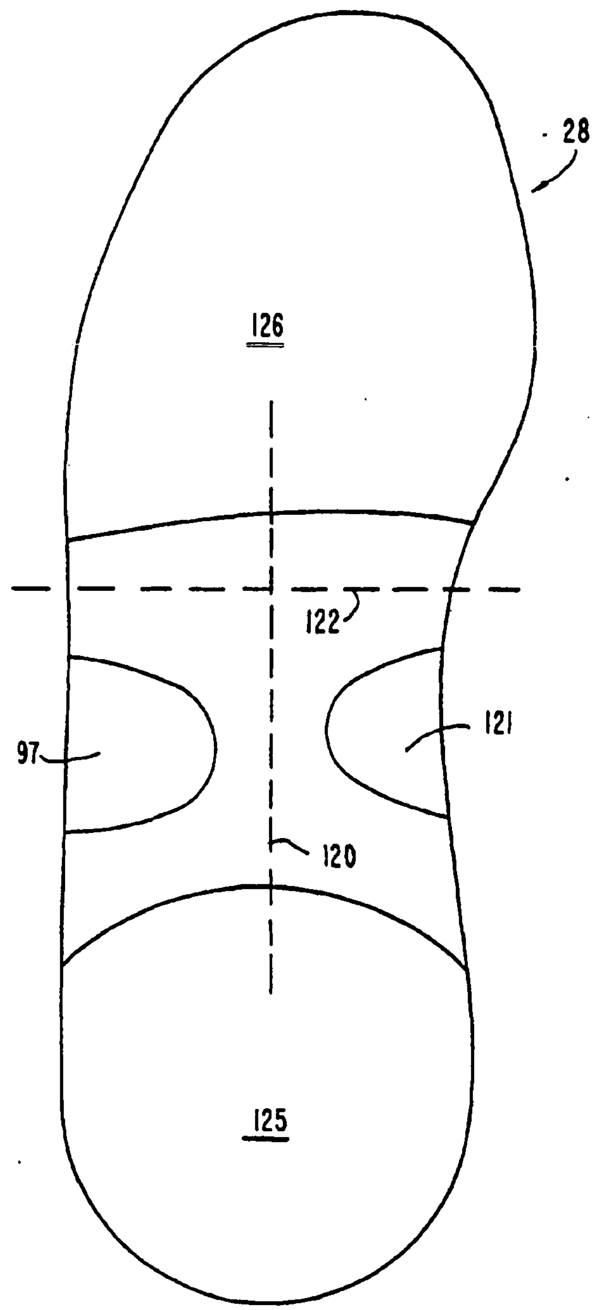


FIG. 29A

FIG. 29

FIG. 29B

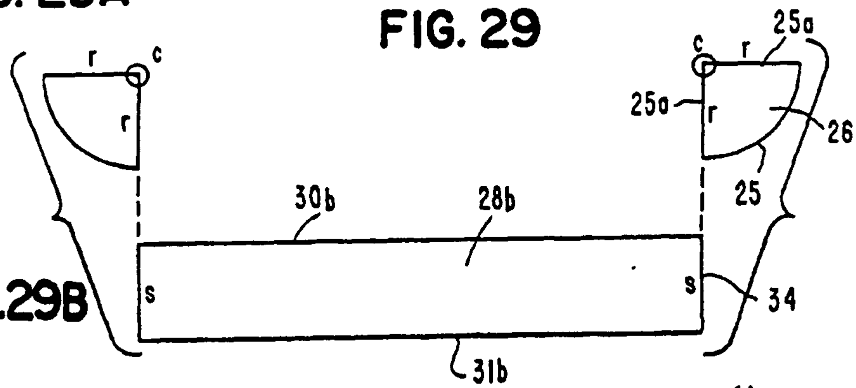


FIG. 29C

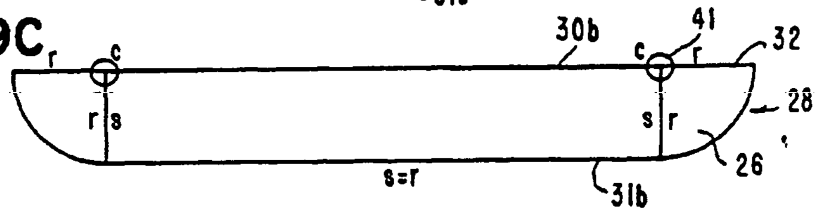


FIG. 30A

FIG. 30

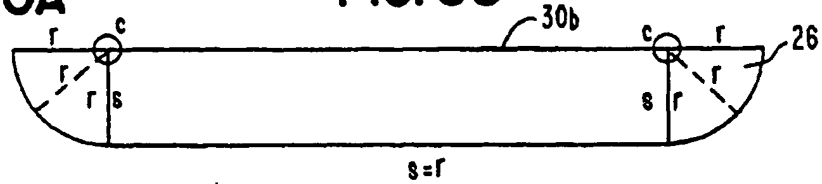


FIG. 30B

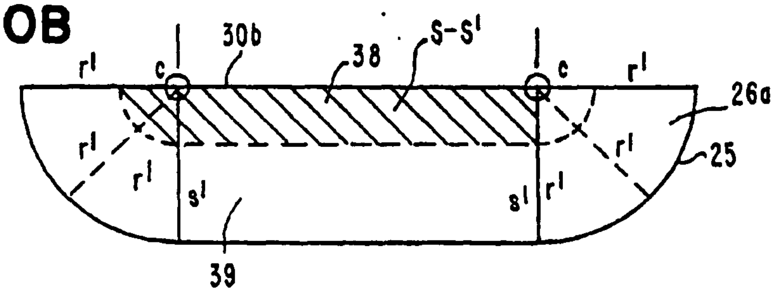


FIG. 31

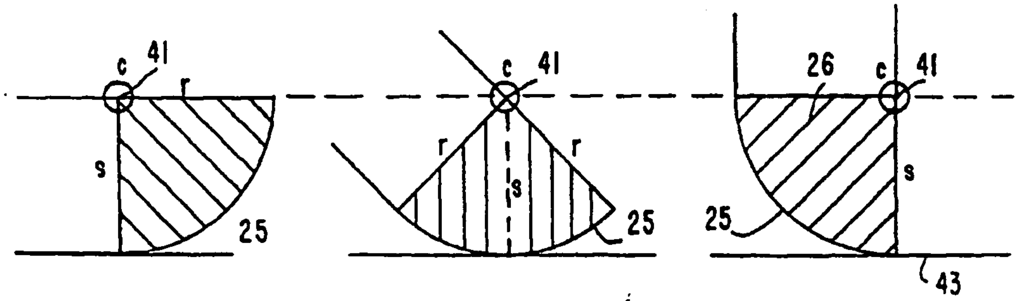


FIG. 32

FIG. 32A

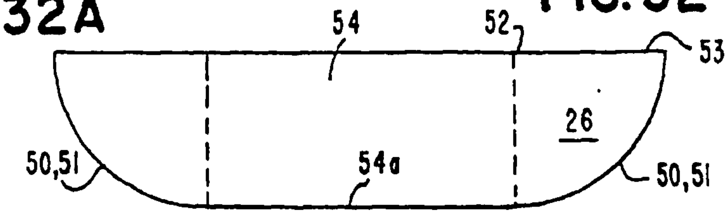


FIG. 32B

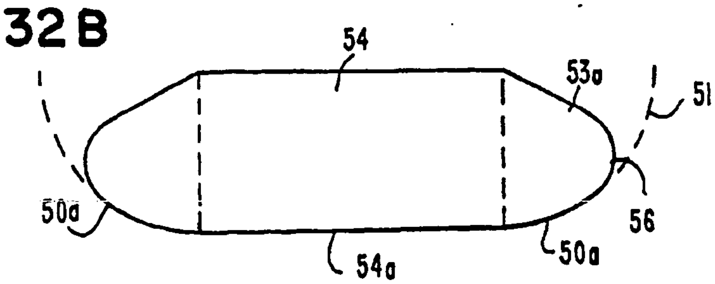


FIG. 32C

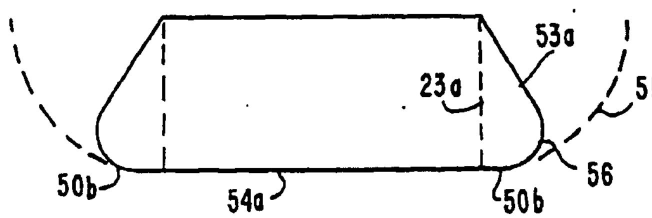


FIG. 33

FIG. 33A

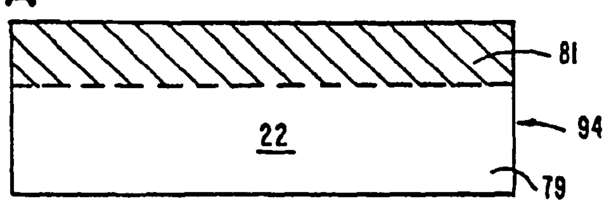


FIG. 33B

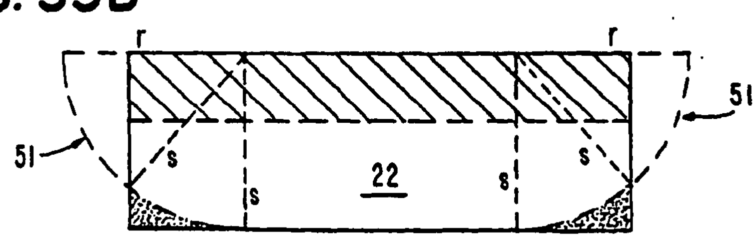


FIG. 34B

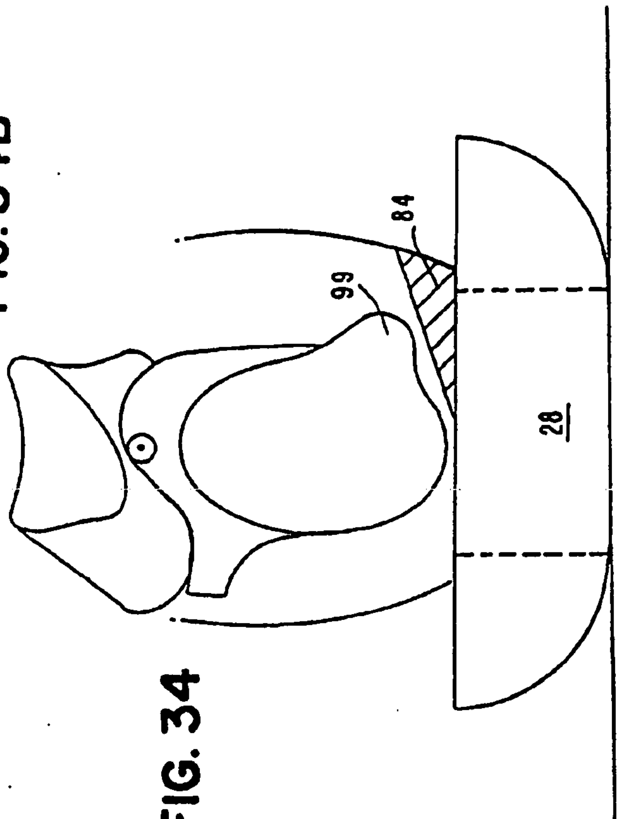


FIG. 34

FIG. 35

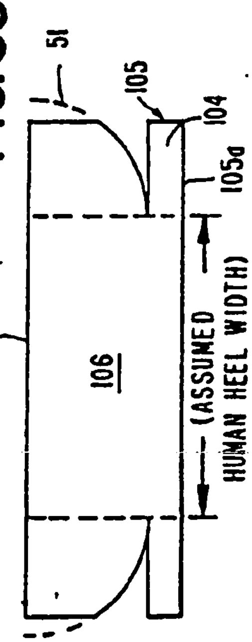


FIG. 33C

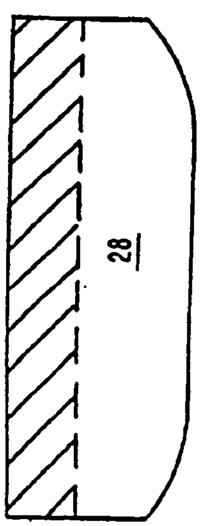


FIG. 34A

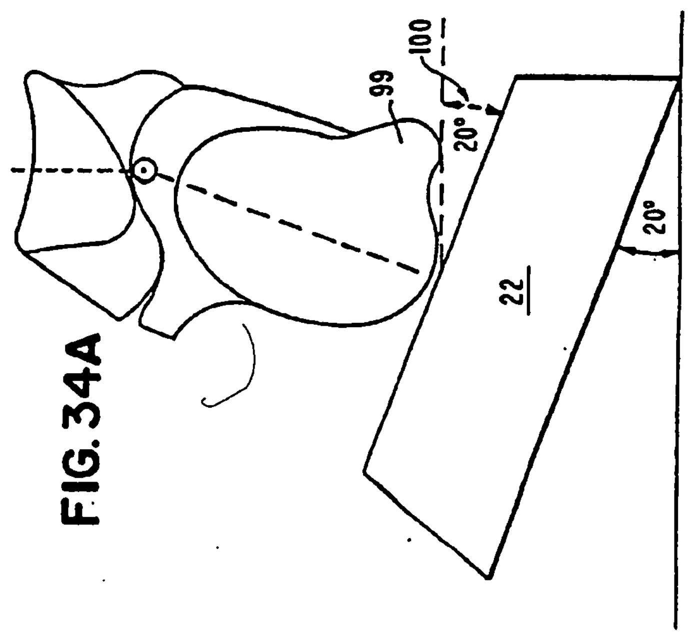


FIG. 36

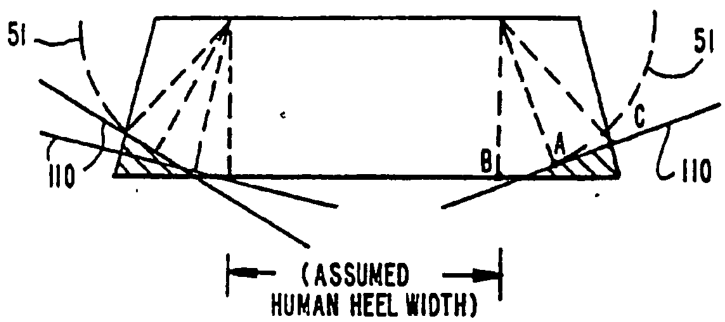


FIG. 37

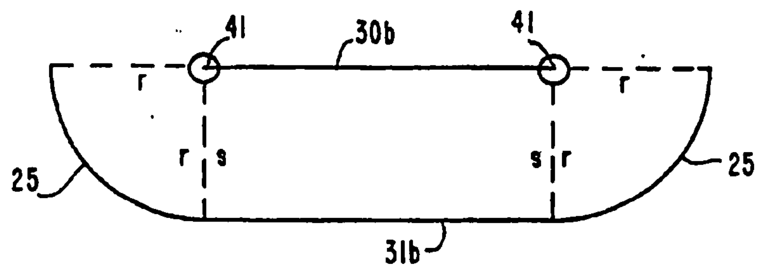
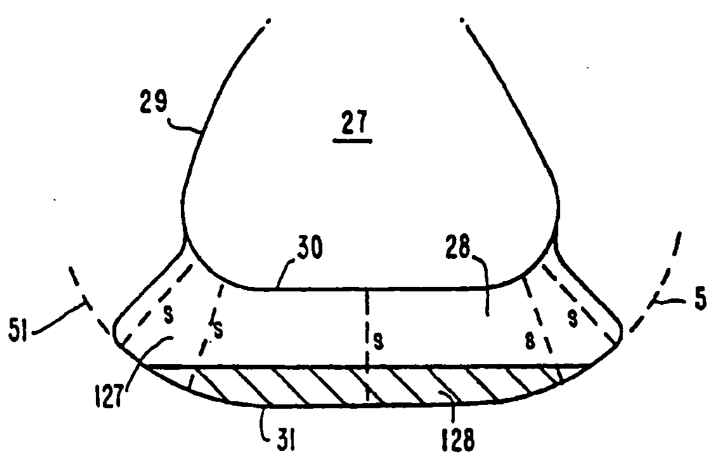


FIG. 38A



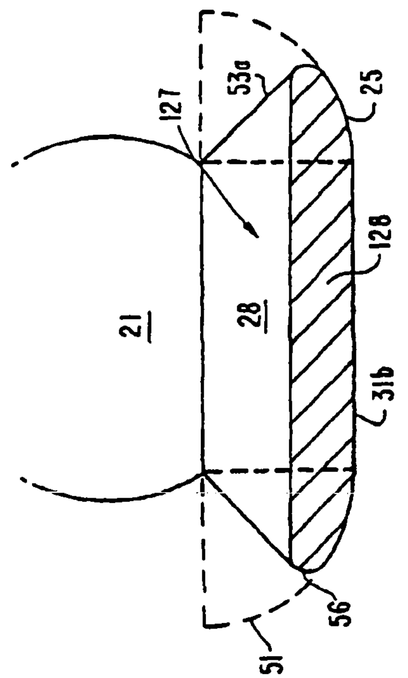


FIG. 38C

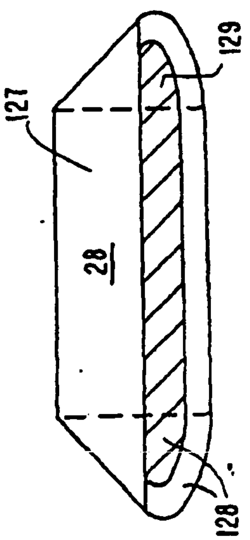


FIG. 38D

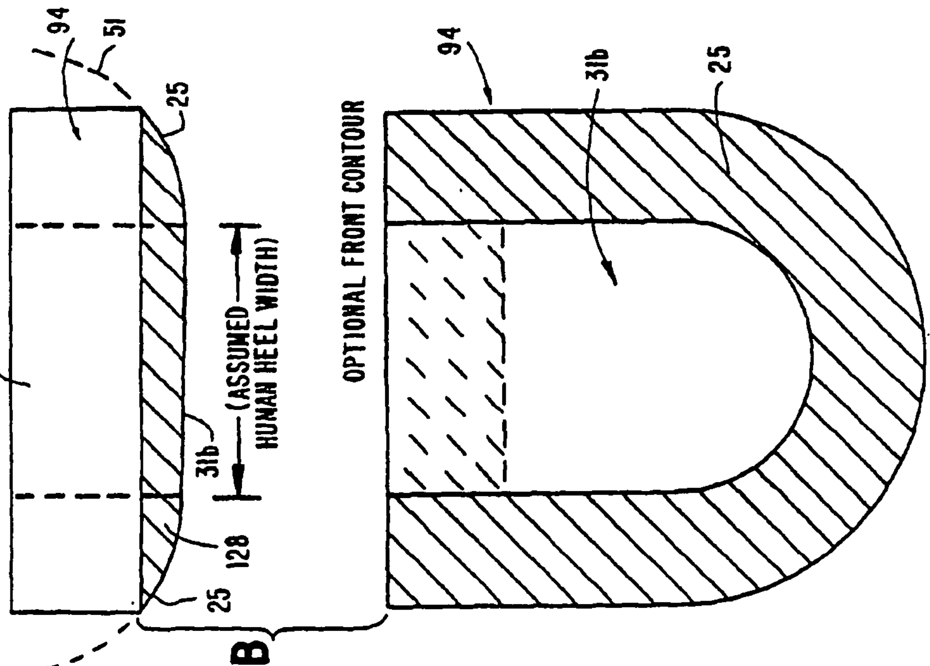


FIG. 38B

FIG. 38E

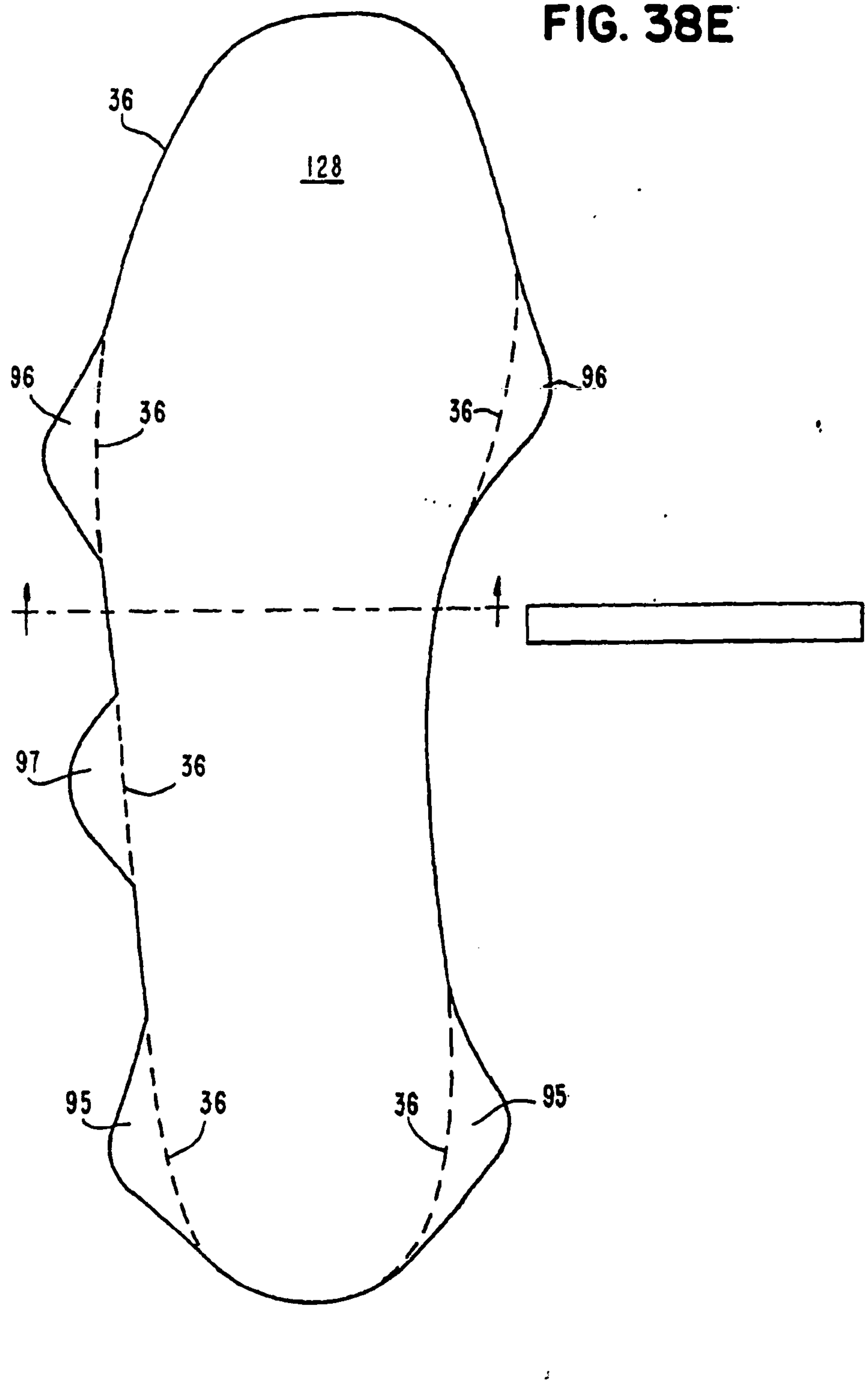


FIG. 39

FIG. 39A

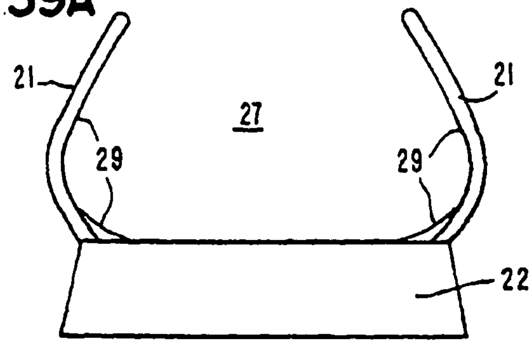


FIG. 39B

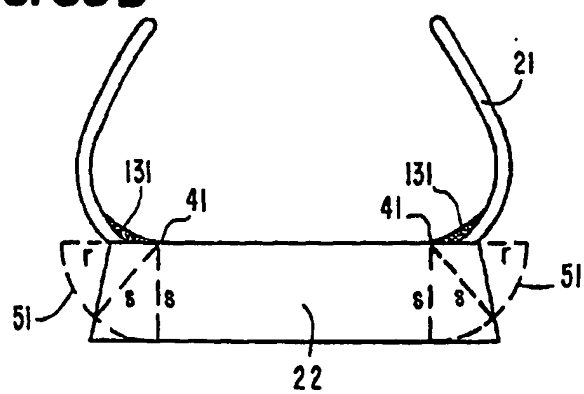


FIG. 39C

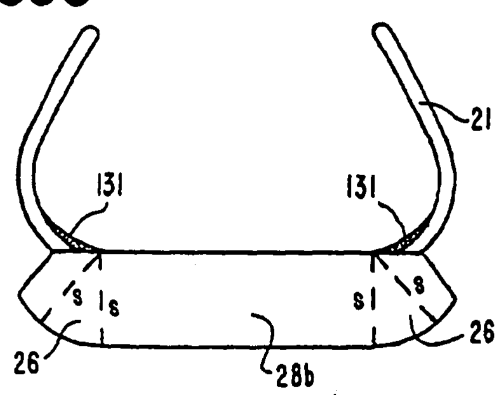


FIG. 40

FIG. 40A

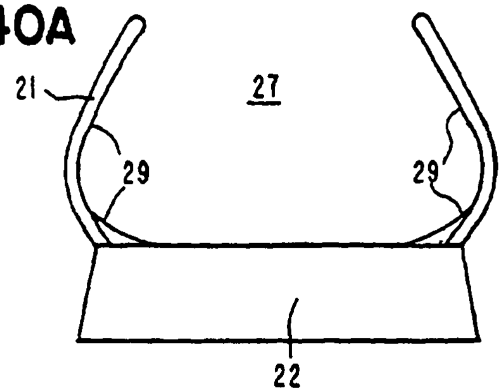


FIG. 40B

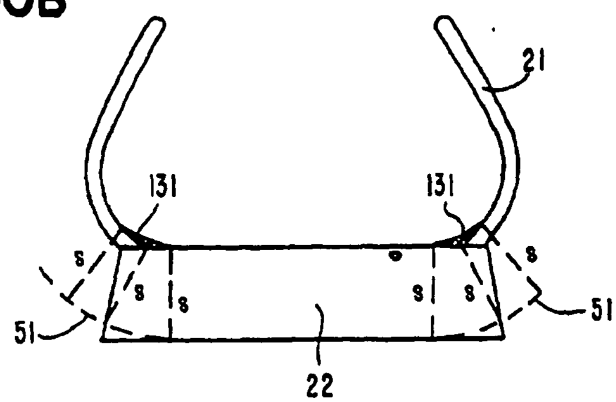
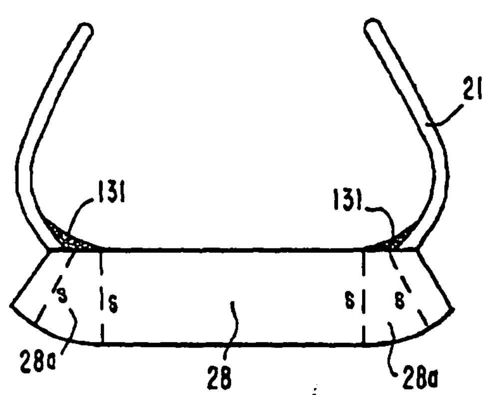


FIG. 40C



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EUROPEAN SEARCH REPORT

Application Number
EP 00 20 4038

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Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int.Cl.7)
X	US 4 694 591 A (BANICH HOWARD P ET AL) 22 September 1987 (1987-09-22) * column 3, line 32 - line 50; claim 2; figure 5 *	1-17	A43B13/00 A43B13/04 A43B13/14
X	US 4 578 882 A (TALARICO II LOUIS C) 1 April 1986 (1986-04-01) * column 6, line 42 - column 7, line 23; figures 1-4 *	1-17	
X	US 4 449 306 A (CAVANAGH PETER R) 22 May 1984 (1984-05-22) * column 3, line 20 - column 4, line 7; figures 1-7 *	1-17	
X	US 4 399 620 A (FUNCK HERBERT) 23 August 1983 (1983-08-23) * abstract; claims 1-3; figures 1-7 *	1-17	
X	US 4 559 723 A (HAMY NORBERT ET AL) 24 December 1985 (1985-12-24) * abstract; claims 1-16; figures 1-8 *	1-17	TECHNICAL FIELDS SEARCHED (Int.Cl.7)
A	US 4 697 361 A (GANTER PAUL ET AL) 6 October 1987 (1987-10-06) * abstract; claim 1; figures 1,8 *	1	A43B
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The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
THE HAGUE	9 April 2001	Suendermann, R

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